UNIVERSIDAD D CÓRDOBA

CONDICIONES DE SEGURIDAD Y SALUD EN LA EXPOSICIÓN DE LOS TRABAJADORES ANTE MYCOBACTERIUM TUBERCULOSIS

TESIS DOCTORAL

FEBRERO DE 2021

PROGRAMA DE DOCTORADO

BIOMEDICINA

DOCTORANDA: MARÍA ESTHER VAQUERO ÁLVAREZ

DIRECTORES: DR. PILAR APARICIO MARTÍNEZ

PROF.DR. MARÍA DOLORES REDEL MACÍAS

TITULO: *Health and safety conditions in workers' exposure to Mycobacterium tuberculosis*

AUTOR: *María Esther Vaquero Álvarez*

Campus de Rabanales
Ctra. Nacional IV, Km. 396 A
14071 Córdoba

https://www.uco.es/ucopress/index.php/es/
ucopress@uco.es

Universidad de Córdoba

Instituto de Estudios de Postgrado

TESIS DOCTORAL

CONDICIONES DE SEGURIDAD Y SALUD EN LA EXPOSICIÓN DE LOS TRABAJADORES ANTE MYCOBACTERIUM TUBERCULOSIS

HEALTH AND SAFETY CONDITIONS IN WORKERS ' EXPOSURE TO MYCOBACTERIUM TUBERCULOSIS

PROGRAMA DE DOCTORADO

BIOMEDICINA

DOCTORANDA: ESTHER VAQUERO ÁLVAREZ

DIRECTORES: PROF. DR. PILAR APARICIO MARTÍNEZ

PROF. DR. MARÍA DOLORES REDEL MACÍAS

Córdoba, Diciembre de 2020

CONDICIONES DE SEGURIDAD Y SALUD EN LA EXPOSICIÓN DE LOS TRABAJADORES ANTE MYCOBACTERIUM TUBERCULOSIS

HEALTH AND SAFETY CONDITIONS IN WORKERS ' EXPOSURE TO MYCOBACTERIUM TUBERCULOSIS

TÍTULO DE LA TESIS:

CONDICIONES DE SEGURIDAD Y SALUD EN LA EXPOSICIÓN DE LOS TRABAJADORES ANTE MYCOBACTERIUM TUBERCULOSIS

HEALTH AND SAFETY CONDITIONS IN WORKERS ' EXPOSURE TO MYCOBACTERIUM TUBERCULOSIS

DOCTORANDA:
ESTHER VAQUERO ÁLVAREZ

INFORME RAZONADO DE LAS DIRECTORAS DE LA TESIS

El trabajo, objeto de esta tesis es original, fruto de un proceso de maduración largo y extenso. En la introducción, la doctoranda demuestra un profundo conocimiento en torno al tema, lo que ha quedado demostrado en un artículo de investigación bibliométrico publicado en la revista International Journal of Environmental Research and Public Health,(JCR Q1) en 2020.

Los objetivos de la investigación están correctamente formulados.

La metodología que emplea es oportuna y coherente con los objetivos formulados y responden a las hipótesis de partida. Además, cumple los requisitos ético-legales exigibles (consentimiento informado, confidencialidad, normas de buena práctica, protección de datos).

Los resultados están expuestos de una manera clara, detallada y meticulosa. En la discusión, la doctoranda hace una interpretación juiciosa y objetiva de los resultados y de su aplicabilidad práctica, comparándolos con los de otros trabajos previos y describiendo las limitaciones y fortalezas del estudio.

Las conclusiones son acordes con los objetivos formulados. La bibliografía está actualizada y es suficientemente amplia.

Los resultados derivados del estudio han sido presentados en eventos científicos de elevado nivel y publicado en la base de datos WOS y publicados en revistas de elevado índice de impacto según la base de datos JCR y SCOPUS.

Comunicaciones a Congresos

- Training in Biosafety against M tuberculosis: experience in the Micobacteria Reference Center at the University of Córdoba, Spain. Vaquero-Álvarez E, López-Roldan P, Aguilar EJ, Palomares F, Torralbo, Vaquero M, Casal MJ XXXIV Annual Congress of the European Society of Mycobacteriology. Florence 30 June - 3 July 2013.
- Apps: an useful tool in the formation of professional exposed to Mycobacterium tuberculosisin the workplace. Vaquero-Álvarez E, Checa-Claudel J, López-Roldan P, Casal M XXXV Annual Congress of the European Society of Mycobacteriology. Vienna 29 June - 2 July 2014.
- Creación de una web móvil: "Portal sanitario para la formación e información e información de los profesionales en el ámbito sanitario:PSAM. Aparicio-Martínez P, Vaquero-Álvarez E, Martínez-Jiménez MP, Vaquero-Abellán M. V Congreso Internacional de Salud Laboral y Prevención de Riesgos. Madrid 8 al 10 de Junio de 2017. Premio a la mejor comunicación.
- New methodologies for preventing exposure to biological agents in the labs. Vaquero Álvarez E, Aparicio-Martínez P, Martínez-Jiménez MP. 10º IMIBIC Young Investigators Meeting (10ª Jornadas de Jóvenes Investigadores). Córdoba 16 al 17 de Mayo de 2019.
- A mobile interactive health application for biological risk prevention in coming hazardous actions: PSAM. Aparicio-Martínez P, Martínez-Jiménez MP, Perea-Moreno A, Vaquero Álvarez E, Redel-Macías MD, Vaquero-Abellán M. International Conference on Medical Physics, Medical Engineering and Informatics (ICMMI 2018). Macau 7 - 9 September 2018
- Proposal for control of ventilation with low-cost sensors that use a standarized and open data management model based on the European FiWare standard. Vaquero-Álvarez E, Checa-Claudel J. 40 European Society of Mycobacteriology Annual Congress. Valencia 30 June - 3 July 2019.
- Management of hazardous infectious waste in a Mycobacteria Reference Center. Vaquero-Álvarez E, Aguilar EJ, Gomera A, Ruíz-Martínez P, deToro A, Guijarro C, Casal M 40 European Society of Mycobacteriology Annual Congress. Valencia 30 June - 3 July 2019.

Los trabajos publicados en revistas de alto índice de impacto se ha realizado bajo la supervisión de la Doctora en Medicina Gabriele Käfer, Directora del Onkologische Institutambulanz SRH Kliniken Landkreis en Sigmaringen, Alemania, desarrollada entre el día 2 de septiembre de 2019 y el 30 de noviembre de 2019, ambos inclusive en la estancia internacional de tres meses realizada por la doctoranda y financiada por la beca de movilidad de la Universidad de Córdoba en 2019.

- Vaquero-Álvarez E, Cubero-Atienza A, Ruiz-Martínez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future. Int. J. Environ. Res. Public Health 2020, 17, 6732; doi:10.3390/ijerph17186732. IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1

- Vaquero-Álvarez E, Cubero-Atienza A, Ruiz-Martínez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Tuberculosis and Other Airborne Microbes in Occupational Health and Safety. Int. J. Environ. Res. Public Health 2020, 17, 7088; doi:10.3390/ijerph17197088. IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1

- Vaquero-Álvarez E, Cubero-Atienza A, Martínez-Jiménez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot. Int. J. Environ. Res. Public Health 2020, 17, 8381; doi:10.3390/ IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1

Asimismo, estos estudios se han financiado con diversos Proyectos de Investigación y divulgación.

Por lo expuesto, la presente tesis cumple todos los requisitos formales de calidad y originalidad, mantiene el rigor científico y académico exigible.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, a 15 de Diciembre de 2020

Firma de las Directoras

REDEL MACIAS MARIA DE LOS DOLORES - 44360005C

Firmado digitalmente por REDEL MACIAS MARIA DE LOS DOLORES - 44360005C
Fecha: 2020.12.16 06:50:20 +01'00'

APARICIO MARTINEZ PILAR - 45943713V

Digitally signed by APARICIO MARTINEZ PILAR - 45943713V
Date: 2020.12.16

Fdo.: Dra. María Dolores Redel Macías Fdo.: Dra. Pilar Aparicio Martínez

ACKNOWLEDGEMENTS

First of all I would like to express my great gratitude to all the people involved who supported me in the preparation of my doctoral thesis.

My special thanks go to my dissertation directors, Dr. Pilar Aparicio and Dr. Maria Dolores Redel, who always encouraged me to be better than yesterday and to keep on improving myself every day.
Each challenge, each article, each chapter of the thesis has made me grow in all aspects. Without their support nothing would have been the same. Thank you infinitely for your confidence and for believing in me.

I would also like to extend my deepest gratitude to Dr. Gabriele Käfer, for her support, who has also accompanied me on this journey with advice, suggestions and productive conversations.

Finally, my deep and sincere gratitude to my family and friends for their continuous help, support, patience and encouragement.

AGRADECIMIENTOS

En primer lugar me gustaría expresar mi gran gratitud a todas las personas involucradas que me apoyaron en la preparación de mi tesis doctoral.

Mi agradecimiento especial va dirigido a mis directoras de tesis, Dr. Pilar Aparicio y Dr. María Dolores Redel, que siempre me animaron a ser mejor que ayer y a seguir mejorando cada día. Cada reto, cada artículo, cada capítulo de la disertación me hizo crecer en todos los aspectos. Sin su apoyo, nada habría sido lo mismo. Gracias enormemente por su confianza y por creer en mí.

También me gustaría expresar mi más profunda gratitud a la Dra. Gabriele Käfer, que me ha acompañado a lo largo de este camino con consejos, sugerencias y conversaciones productivas, por su apoyo.

Por último, mi más profundo y sincero agradecimiento a mi familia y amigos por su constante ayuda, apoyo, paciencia y aliento.

DANKSAGUNG

An dieser Stelle möchte ich allen beteiligten Personen meinen großen Dank aussprechen, die mich bei der Anfertigung meiner Dissertation unterstützt haben.

Mein besonderer Dank gilt meine Dissertationsleiterinnen, Dr. Pilar Aparicio und Maria Dolores Redel, die mich immer ermutigt haben, besser zu sein als gestern und mich jeden Tag weiter zu verbessern.
Jede Herausforderung, jeder Artikel, jedes Kapitel der Dissertation hat mich in allen Aspekten wachsen lassen. Ohne ihre Unterstützung wäre nichts das Gleiche gewesen. Ich danke Ihnen unendlich für Ihr Vertrauen und dafür, dass Sie an mich geglaubt haben.

Auch Frau Dr. Gabriele Käfer, die mich auf diesem Weg mit Ratschlägen, Anregungen und produktiven Gesprächen begleitet hat, möchte ich meinen tiefsten Dank für ihre Unterstützung aussprechen.

Schließlich gilt mein tiefer und aufrichtiger Dank meiner Familie und meinen Freunden für ihre ständige Hilfe, Unterstützung, Geduld und Ermutigung.

INDEX

FIGURE CAPTIONS

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER V

CHAPTER VI

Chapter 0. Summary

0.1. Summary

Introduction

Health workers are exposed to different biological pathogens, which implies a risk to their health and a cost to the system. In this population, the rate of work-related accidents and diseases is higher than desired (up to 3.2%). Airborne pathogens and infectious diseases such as tuberculosis are highly contagious and can have serious effects on health workers. Symptoms of these diseases are slow to appear, which may prevent workers from realizing that they have been exposed until symptoms appear. Among these pathogens, tuberculosis (TB) remains one of the top ten preventable causes of death. The worrying thing is that about 10 million people have suffered from TB.

Many factors can contribute to accidental exposure to a biological agent, although the main ones remain lack of experience, skills or knowledge in handling materials, and anxiety, fatigue and lack of care from oneself or other professionals. In the case of TB, lack of knowledge about transmission, appropriate preventive and biosecurity measures; and diagnosis of the disease appear to play an important role.

Germany has a lower rate of infection and incidence of TB than Spain, which suppose a risk for health care workers. Also, the World Health Organization (WHO) has highlighted the importance of regularly reviewing national programmes, especially plans and policies based on monitoring, reporting and recommendations. Training plans have been designed and implemented to raise awareness of risk and prevention among health workers. More attractive environments for health training have been created to improve health workers' knowledge and skills, such as virtual environments in surgery. Technological tools have changed the way people interact in their environment since the 1980s. At the same time, occupational health and safety measures have been widely implemented. The European Agency for Safety and Health at Work sees information and communication technologies as the main methods for achieving the proposed objectives of improving working life and disseminating good practice.

The objetctive from this dissertation were:

-To determine the link between ICT, occupational safety and pathogens

-To evaluate the preventive and occupational safety measures carried out in mycobacteriology laboratories in the European Union and other continents.

-To estimate the degree of protection of health workers against risks related to exposure to biological agents at work.

- To compare the preventive guides or protocols in Germany and Spain.

- To determine the efficacy of a educational approach based on tehcnology to quantify knowledge and prevention culture.
- To design, implement and evaluate a Virtual Laboratory (VL) for the training of workers exposed to risks from biological agents.

Material and Methods

A bibliometric study was carried out to find out the trends in publications focused on new technologies and occupational safety in the health sector over the last 30 years, using the database Scopus.

To respond to the second and third objectives, an observational, cross-sectional descriptive study was carried out on a sample of workers in Mycobacteria laboratories in the European Union, and others worldwide, using an original and specific questionnaire that evaluates preventive and safety measures at work.

In response to the fourth objective, protocols for TB prevention in Spain and Germany were studied, analysing: case notification and follow-up, treatment of latent TB, chemoprophylaxis, methods of diagnosis and treatment of TB, as well as TB care programmes.

Prospective observational educational research was carried out to quantify student knowledge and prevention culture.

Finally, to obtain the Virtual Laboratory, a learning methodology on occupational health and safety was applied with a technological approach focused on health workers. The design and the diagram of the creation were based on: feedback, attractive experience, creative design and evaluation of the designed programme.

Results

A total of 1021 documents were located, showing an increasing trend by country, especially in the United States ($p < 0.001$), and by year ($p < 0.001$). Annual citations showed significant differences between articles published before 2007 ($p < 0.001$). The year was also linked to the variation in the publication of articles on ICT, occupational safety and health in the health sector (72.2%) and literature reviews (14.9%) ($p < 0.001$). The most significant previous publication was a report (848 citations) indicating that the above variables linked to exposure are vital for prevention. Most of the papers were reviews ($p = 0.009$) with a limited number of studies on occupational safety.

Occupational safety and health measures were found to be inadequate, according to the workers' opinion. Training ($p < 0.01$), workload ($p < 0.05$), and monitoring of protocols ($p < 0.001$) were related to incidents and exposure to airborne pathogens.

Both Spain and Germany have committed to establish guidelines for the prevention of TB in order to achieve the goals proposed by the WHO at the global level. Both countries agree on case reporting, chemoprophylaxis and treatment of latent TB. And it is essential that TB control improves the level of knowledge of health care professionals and staff, but of course also of those affected by their environment.

The results on the educational approach based on the development of a technological tool, its integration in the training of students and the subsequent evaluation, prior to the integration of the educational approach, showed differences between basic and proficient knowledge and correct procedure in each academic year ($p < 0.05$), the best year being the third academic year. The average elementary knowledge among second year students after the inclusion of the educational methodology based on information and communication technologies (ICT) improved for the academic year 2017/2018 with an average of 7.5 (1.11) and in 2018/2019 with 7.87 (1.34). This argued that the proposed educational approach could improve the culture and knowledge of prevention among students and future health professionals.

The results showed that the prototype of the Virtual Laboratory was very well defined, but more profound modifications of the context and process were needed, especially to improve its attractiveness and usefulness (5/7). The current study continues to be developed and the future implications will be the integration and use among the end-user's group of health workers to determine the usefulness of the technological approach created.

Conclusions

There is a growing number of publications on ICT, occupational safety and health in the health sector, although it seems that the most significant development of ICT for this field is yet to come. The hygiene behaviour and measures of Spanish workers are still unsafe and poor compared to other European workers. Although in Spanish workers as well as in workers from other European countries, from North and South America, the risks arising from exposure to airborne pathogens may be related to the lack of training and continuing education.

Also, to reduce the risk among workers, greater compliance with occupational safety and health standards, monitoring of preventive measures and more research focused on monitoring these measures are needed.

Germany and Spain share common actions in education, the search for the best treatments by a multidisciplinary team. They also agree on the importance of training, avoiding work overload and the way in which workers follow the relevant protocols.

The new teaching methodologies, based on ICTs as a mixed model, improve the culture and knowledge of prevention among students and future health professionals. And dinnaly, the

initial version of a Virtual Laboratory (VL) has been designed on a platform that includes different scenarios of exposure to biological agents, and aims to create a virtual online learning experience to improve knowledge of the risks of exposed workers, as well as the main measures for the control and prevention of pathogens. The evaluation of the platform showed that the users' opinion on the inclusion of this technology-based educational approach is satisfactory.

Resumen

Introducción

Los trabajadores de la salud están expuestos a diferentes patógenos biológicos, lo que implica un riesgo para su salud y un costo para el sistema. En esta población, la tasa de accidentes y enfermedades relacionadas con el trabajo es más alta de lo deseado (hasta el 3,2%).

Los patógenos de transmisión aérea y las enfermedades infecciosas como la tuberculosis, son muy contagiosos y pueden tener efectos graves para los trabajadores de la salud. Los síntomas de estas enfermedades tardan en manifestarse, lo que puede impedir que los trabajadores se den cuenta de que han estado expuestos hasta que aparecen los síntomas.

La tuberculosis (TB) sigue siendo una de las diez principales causas de muerte prevenibles. El tema preocupante es que alrededor de 10 millones de personas sufrieron de TB.

Muchos factores pueden contribuir a la exposición accidental a un agente biológico, aunque los principales siguen siendo la falta de experiencia, habilidades o conocimientos en el manejo de materiales, y la ansiedad, la fatiga y la falta de cuidado de uno mismo o de otros profesionales. En el caso de la tuberculosis, la falta de conocimientos sobre su transmisión, las medidas preventivas y de bioseguridad apropiadas; y el diagnóstico de la enfermedad parecen desempeñar un papel importante.

Alemania tiene una tasa de infección y una incidencia de tuberculosis más baja que España. Esta prevalencia de la TB es un riesgo para los trabajadores de la salud. Basándose en la Organización Mundial de la Salud (OMS) que destacó la importancia de revisar periódicamente los programas nacionales, especialmente los planes y políticas basados en la supervisión, la presentación de informes y las recomendaciones, el presente estudio tuvo como objetivo determinar las diferencias de prevención de la TB entre los dos países europeos a través de los protocolos de prevención alemanes y españoles.

Se han diseñado y puesto en práctica planes de formación para concienciar a los trabajadores sanitarios sobre el riesgo y la prevención. Se han creado entornos más atractivos para la formación en el ámbito de la salud con el fin de mejorar conocimientos y habilidades de los trabajadores sanitarios, como los entornos virtuales en cirugía.

Las herramientas tecnológicas han cambiado la forma en que las personas interactúan en su entorno desde los años 80. Al mismo tiempo, las medidas de salud y seguridad en el trabajo se han aplicado ampliamente. La Agencia Europea para la Seguridad y la Salud en el Trabajo considera que las tecnologías de la información y la comunicación son los principales métodos para lograr los objetivos propuestos de mejorar la vida laboral y la difusión de buenas prácticas.

Los objetivos de esta tesis fueron:

-Determinar el vínculo entre TIC, seguridad laboral y agentes patógenos.

-Evaluar las medidas preventivas y de seguridad laboral que se llevan a cabo en los laboratorios de micobacteriología de la Unión Europea y otros continentes.

-Estimar el grado de protección del personal sanitario frente a los riesgos relacionados con la exposición a agentes biológicos en el trabajo.

- Comparación de las guías o protocolos preventivos de Alemania y España.

- Se llevó a cabo una investigación educativa observacional prospectiva enfocada a cuantificar el conocimiento de los estudiantes y la cultura de prevención.

- Diseñar, implementar y evaluar un Laboratorio Virtual (LV) para la formación de los trabajadores expuestos a riesgos por agentes biológicos.

Material y Métodos

Se realizó un estudio bibliométrico para conocer las tendencias de las publicaciones enfocadas a las nuevas tecnologías y la seguridad ocupacional en el sector de la salud durante los últimos 30 años.

Para responder a los objetivos segundo y tercero, se realizó un estudio observacional, descriptivo transversal en una muestra de trabajadores de laboratorios de Micobacteras de la Unión Europea, y otros a nivel mundial, mediante un cuestionario original y específico que evalúa las medidas preventivas y de seguridad laboral

Se estudiaron, como respuesta al cuarto objetivo, los protocolos sobre prevención de la tuberculosis en España y Alemania, analizando: notificación y seguimiento de casos, tratamiento de la tuberculosis latente, quimioprofilaxis, métodos de diagnóstico y tratamiento de la tuberculosis, así como programas de atención a la enfermedad.

Se llevó a cabo una investigación educativa observacional prospectiva enfocada a cuantificar el conocimiento de los estudiantes y la cultura de prevención.

Por último, para obtener el Laboratorio Virtual se aplicó una metodología de aprendizaje sobre salud y seguridad ocupacional cuyo enfoque tecnológico se centró en los trabajadores sanitarios. El diseño y el diagrama de la creación se basaron en: retroalimentación, experiencia atractiva, diseño creativo y evaluación del programa diseñado.

Resultados

Se localizaron 1021 documentos que mostraron una tendencia creciente por país, especialmente en Estados Unidos ($p < 0{,}001$), y por año ($p < 0{,}001$). Las citas anuales mostraron diferencias significativas entre los artículos publicados antes de 2007 ($p < 0{,}001$). El año también estuvo vinculado a la variación en la publicación de artículos sobre TIC, la seguridad y la salud

ocupacional en el sector sanitario (72,2%) y reseñas bibliográficas (14,9%) (p <0,001). La publicación previa más significativa fue un informe (848 citas) que indica que las variables anteriores vinculadas a la exposición son vitales para la prevención. La mayoría de los trabajos fueron revisiones (p= 0,009) con un número limitado de estudios sobre seguridad laboral.

Las medidas de seguridad y salud en el trabajo resultaron inadecuadas, según la opinión de los trabajadores. La formación (p <0,01), la carga de trabajo (p <0,05), y el seguimiento de los protocolos (p <0,001) se relacionaron con incidentes y exposición a patógenos en el aire.

Tanto España como Alemania se han comprometido a establecer directrices para la prevención de la tuberculosis a fin de alcanzar los objetivos propuestos por la OMS a nivel mundial. Ambos países están de acuerdo en la notificación de casos, la quimioprofilaxis y el tratamiento de la tuberculosis latente. Y es esencial que el control de la tuberculosis mejore el nivel de conocimientos de los profesionales y el personal de atención de la salud, pero, por supuesto, también de los afectados por su entorno.

Los resultados sobre el enfoque educativo basado en el desarrollo de una herramienta tecnológica, su integración en la formación de los estudiantes y la evaluación posterior, previo a la integración del enfoque educativo, mostraron diferencias entre el conocimiento elemental y proficiente, y el correcto procedimiento en cada año académico (p <0.05), siendo el mejor año el tercer año académico. La media de conocimientos elementales entre los estudiantes de segundo año tras la inclusión de la metodología educativa basada en las tecnologías de la información y de la comunicación (TIC) mejoró para el curso 2017/2018 con una media de 7,5 (1,11) y en el 2018/2019 con 7,87 (1,34). Lo que argumentó que el enfoque educativo propuesto podría mejorar la cultura y el conocimiento de la prevención entre los estudiantes y futuros profesionales de la salud.

Los resultados mostraron que el prototipo del Laboratorio Virtual estaba muy definido, pero se necesitaban modificaciones más profundas del contexto y el proceso, especialmente para mejorar el atractivo y la utilidad (5/7). El estudio actual continúa desarrollándose y las implicaciones futuras serán la integración y el uso entre el grupo de trabajadores sanitarios del usuario final para determinar la utilidad del enfoque tecnológico creado.

Conclusiones

Existe un número creciente de publicaciones sobre las TIC, la seguridad y la salud ocupacional en el sector sanitario, aunque parece que el desarrollo más significativo de las TIC para este campo está aún por venir.

Los comportamientos y las medidas higiénicas de los trabajadores españoles siguen siendo inseguros y pobres en comparación con los de otros trabajadores europeos. Aunque tanto en los trabajadores españoles como en los de otros países europeos, de América del Norte y América del Sur, los riesgos derivados de la exposición a los patógenos transmitidos por el aire pueden estar relacionados con la falta de formación y educación continua.

Para reducir el riesgo entre los trabajadores, es necesario un mayor cumplimiento de las normas de seguridad y salud en el trabajo, la vigilancia de las medidas preventivas y la realización de más investigaciones centradas en la supervisión de dichas medidas.

Alemania y España comparten acciones comunes en la educación del paciente, la búsqueda de los mejores tratamientos y el cuidado de los pacientes y sus familias por un equipo multidisciplinar. También coinciden en la importancia de la formación, evitar sobrecarga de trabajo y la forma en que los trabajadores siguieron los protocolos pertinentes.

Las nuevas metodologías de enseñanza, basadas en las TIC como modelo mixto, mejoran la cultura y el conocimiento de la prevención entre los estudiantes y los futuros profesionales de la salud.

Se ha diseñado la versión inicial de un Laboratorio Virtual (LV) en una plataforma que incluye diferentes escenarios de exposición a agentes biológicos, y tiene el propósito de crear una experiencia virtual de aprendizaje en línea para mejorar el conocimiento de los riesgos de los trabajadores expuestos, así como las principales medidas de control y prevención de los patógenos. La evaluación de la plataforma mostró que la opinión de los usuarios sobre la inclusión de este enfoque educativo basado en la tecnología es satisfactoria.

Zusammenfassung

Einführung

Mitarbeiter im Gesundheitswesen sind verschiedenen biologischen Krankheitserregern ausgesetzt, was ein Risiko für ihre Gesundheit und Kosten für das System darstellt. In dieser Bevölkerung ist die Rate der arbeitsbedingten Unfälle und Krankheiten höher als gewünscht (bis zu 3,2 %).

Über die Luft übertragene Krankheitserreger und Infektionskrankheiten wie Tuberkulose sind hoch ansteckend und können schwerwiegende Auswirkungen auf das Gesundheitspersonal haben. Die Symptome dieser Krankheiten manifestieren sich nur langsam, was dazu führen kann, dass Arbeiter nicht erkennen, dass sie exponiert waren, bis Symptome auftreten.

Tuberkulose (TB) gehört nach wie vor zu den zehn häufigsten vermeidbaren Todesursachen. Das Besorgniserregende ist, dass etwa 10 Millionen Menschen an TB erkrankt sind.

Viele Faktoren können zu einer versehentlichen Exposition gegenüber einem biologischen Arbeitsstoff beitragen, obwohl die wichtigsten nach wie vor mangelnde Erfahrung, Fähigkeiten oder Kenntnisse im Umgang mit Materialien sowie Angst, Müdigkeit und mangelnde Sorgfalt von einem selbst oder anderen Fachleuten sind. Im Falle der Tuberkulose scheinen mangelnde Kenntnisse über die Übertragung, geeignete Präventions- und Biosicherheitsmaßnahmen und die Diagnose der Krankheit eine wichtige Rolle zu spielen.

Deutschland hat eine niedrigere Infektionsrate und Inzidenz von TB als Spanien. Diese Prävalenz von TB ist ein Risiko für Mitarbeiter des Gesundheitswesens. Basierend auf der Weltgesundheitsorganisation (WHO), die die Wichtigkeit der regelmäßigen Überprüfung nationaler Programme, insbesondere von Plänen und Richtlinien auf der Grundlage von Überwachung, Berichterstattung und Empfehlungen hervorhob, zielte diese Studie darauf ab, die Unterschiede in der TB-Prävention zwischen den beiden europäischen Ländern anhand der deutschen und spanischen Präventionsprotokolle zu ermitteln.

Es wurden Schulungspläne entworfen und umgesetzt, um das Risiko- und Präventionsbewusstsein des Gesundheitspersonals zu schärfen. Es wurden attraktivere Umgebungen für die Ausbildung im Gesundheitsbereich geschaffen, um die Kenntnisse und Fähigkeiten des medizinischen Personals zu verbessern, wie z. B. virtuelle Umgebungen in der Chirurgie.

Technologische Hilfsmittel haben die Art und Weise, wie Menschen in ihrer Umgebung interagieren, seit den 1980er Jahren verändert. Gleichzeitig wurden Maßnahmen zur Gesundheit und Sicherheit am Arbeitsplatz weitgehend umgesetzt. Die Europäische Agentur für Sicherheit

und Gesundheitsschutz am Arbeitsplatz ist der Ansicht, dass die Informations- und Kommunikationstechnologien die wichtigsten Methoden sind, um die vorgeschlagenen Ziele der Verbesserung des Arbeitslebens und der Verbreitung bewährter Verfahren zu erreichen.

Ziele

-Bestimmung des Zusammenhangs zwischen IKT, Arbeitssicherheit und Krankheitserregern

-Evaluierung der Präventiv- und Arbeitssicherheitsmaßnahmen, die in mykobakteriologischen Laboratorien in der Europäischen Union und anderen Kontinenten durchgeführt werden.

-Bewertung des Schutzes des Gesundheitspersonals vor Risiken im Zusammenhang mit der Exposition gegenüber biologischen Arbeitsstoffen bei der Arbeit

- Vergleich von Präventionsleitlinien oder -protokollen in Deutschland und Spanien.

- Es wurde eine prospektive, beobachtende Bildungsforschung durchgeführt, die sich auf die Quantifizierung des Wissens und der Präventionskultur der Schüler konzentrierte.

- Entwurf, Implementierung und Evaluierung eines Virtuellen Labors (VL) für die Schulung von Arbeitern, die Risiken durch biologische Arbeitsstoffe ausgesetzt sind.

Material und Methoden

In einer bibliometrischen Studie wurde untersucht, wie sich die Publikationen zum Thema Neue Technologien und Arbeitsschutz im Gesundheitswesen in den letzten 30 Jahren entwickelt haben. Um dem zweiten und dritten Ziel gerecht zu werden, wurde eine deskriptive Beobachtungs- und Querschnittsstudie an einer Stichprobe von Arbeitern aus Mykobakterien-Laboratorien in der Europäischen Union und anderen weltweit durchgeführt, wobei ein origineller und spezifischer Fragebogen verwendet wurde, der Präventions- und Arbeitsschutzmaßnahmen bewertet

Als Antwort auf das vierte Ziel wurden die Protokolle zur Prävention von Tuberkulose in Spanien und Deutschland untersucht, wobei Folgendes analysiert wurde: Fallmeldung und Nachsorge, Behandlung der latenten Tuberkulose, Chemoprophylaxe, Methoden der Diagnose und Behandlung von Tuberkulose sowie Pflegeprogramme für die Krankheit.

Es wurde eine prospektive, beobachtende Bildungsforschung durchgeführt, die sich auf die Quantifizierung von Schülerwissen und Präventionskultur konzentrierte.

Um das virtuelle Labor zu erhalten, wurde schließlich eine Lernmethodik zum Thema Gesundheit und Sicherheit am Arbeitsplatz mit einem technologischen Ansatz angewandt, der sich auf Mitarbeiter im Gesundheitswesen konzentriert. Der Entwurf und das Diagramm der

Erstellung basierten auf: Feedback, attraktiven Erfahrungen, kreativem Design und der Bewertung des entwickelten Programms.

Ergebnisse

Insgesamt wurden 1021 Dokumente gefunden, die einen zunehmenden Trend nach Land, insbesondere in den Vereinigten Staaten ($p < 0,001$), und nach Jahr ($p < 0,001$) zeigen. Jährliche Zitationen zeigten signifikante Unterschiede zwischen Artikeln, die vor 2007 veröffentlicht wurden ($p < 0,001$). Das Jahr war auch mit der Variation bei der Veröffentlichung von Artikeln über IKT, Arbeitssicherheit und Gesundheitsschutz im Gesundheitswesen (72,2 %) und Literaturübersichten (14,9 %) verbunden ($p < 0,001$). Die wichtigste frühere Veröffentlichung war ein Bericht (848 Zitate), der darauf hinwies, dass die früheren Variablen, die mit der Exposition zusammenhängen, für die Prävention entscheidend sind. Die meisten Arbeiten waren Reviews ($p = 0,009$) mit einer begrenzten Anzahl von Studien zur Arbeitssicherheit.

Die Maßnahmen zur Arbeitssicherheit und zum Gesundheitsschutz wurden nach Meinung der Arbeiter als unzureichend empfunden. Schulung ($p < 0,01$), Arbeitsbelastung ($p < 0,05$) und Nachverfolgung von Protokollen ($p < 0,001$) standen im Zusammenhang mit Zwischenfällen und der Exposition gegenüber luftgetragenen Krankheitserregern.

Sowohl Spanien als auch Deutschland setzen sich für die Erstellung von Richtlinien zur Tuberkuloseprävention ein, um die von der WHO vorgeschlagenen Ziele auf globaler Ebene zu erreichen. Beide Länder sind sich einig über Fallmeldungen, Chemoprophylaxe und Behandlung der latenten Tuberkulose. Und es ist wichtig, dass die Tuberkulosebekämpfung den Wissensstand des Gesundheitspersonals und der Mitarbeiter, aber natürlich auch der Betroffenen in ihrem Umfeld verbessert.

Die Ergebnisse zum pädagogischen Ansatz, der auf der Entwicklung eines technologischen Werkzeugs, seiner Integration in die Ausbildung der Studenten und der anschließenden Bewertung basiert, zeigten Unterschiede zwischen elementaren und geübten Kenntnissen und korrektem Vorgehen in jedem Studienjahr ($p < 0,05$), wobei das beste Jahr das dritte Studienjahr war. Die durchschnittlichen Elementarkenntnisse der Schüler des zweiten Studienjahres verbesserten sich nach der Einbeziehung der auf Informations- und Kommunikationstechnologien (IKT) basierenden Unterrichtsmethode im Studienjahr 2017/2018 mit einem Durchschnitt von 7,5 (1,11) und im Studienjahr 2018/2019 mit 7,87 (1,34). Dies spricht dafür, dass der vorgeschlagene pädagogische Ansatz die Kultur und das Wissen über Prävention bei Studenten und zukünftigen Gesundheitsfachkräften verbessern könnte.

Die Ergebnisse zeigten, dass der Prototyp des Virtuellen Labors sehr gut definiert war, aber tiefgreifendere Modifikationen des Kontexts und des Prozesses notwendig waren, insbesondere um die Attraktivität und Nützlichkeit zu verbessern (5/7). Die aktuelle Studie entwickelt sich weiter und die zukünftigen Implikationen werden die Integration und der Einsatz in der Gruppe der Endanwender im Gesundheitswesen sein, um die Nützlichkeit des geschaffenen technologischen Ansatzes zu bestimmen.

Schlussfolgerungen

Es gibt eine wachsende Zahl von Veröffentlichungen über IKT, Arbeitssicherheit und Gesundheitsschutz im Gesundheitssektor, obwohl es scheint, dass die bedeutendste Entwicklung der IKT für diesen Bereich noch bevorsteht.

Das Hygieneverhalten und die Hygienemaßnahmen der spanischen Arbeiter sind im Vergleich zu anderen europäischen Arbeitern immer noch unsicher und schlecht. Obwohl sowohl bei spanischen als auch bei anderen europäischen Arbeitnehmern in Nord- und Südamerika die Risiken, die sich aus der Exposition gegenüber luftgetragenen Krankheitserregern ergeben, möglicherweise mit der mangelnden Aus- und Weiterbildung zusammenhängen.

Um das Risiko unter den Arbeitnehmern zu verringern, sind eine stärkere Einhaltung der Normen für Sicherheit und Gesundheitsschutz bei der Arbeit, die Überwachung von Präventivmaßnahmen und mehr Forschung, die sich auf die Überwachung dieser Maßnahmen konzentriert, erforderlich.

Deutschland und Spanien haben gemeinsame Aktionen in der Patientenaufklärung, der Suche nach den besten Behandlungsmethoden und der Betreuung von Patienten und ihren Familien durch ein multidisziplinäres Team. Sie sind sich auch einig über die Bedeutung von Schulungen, die Vermeidung von Arbeitsüberlastung und die Art und Weise, wie die Arbeiter die entsprechenden Protokolle befolgten.

Die neuen Lehrmethoden, die auf IKT als gemischtes Modell basieren, verbessern die Kultur und das Wissen über Prävention bei Studenten und zukünftigen Gesundheitsfachkräften.

Die erste Version eines Virtuellen Labors (VL) wurde auf einer Plattform entwickelt, die verschiedene Szenarien der Exposition gegenüber biologischen Arbeitsstoffen enthält und darauf abzielt, eine virtuelle Online-Lernerfahrung zu schaffen, um das Wissen über die Risiken der exponierten Arbeitnehmer sowie die wichtigsten Maßnahmen zur Kontrolle und Prävention von Krankheitserregern zu verbessern. Die Evaluierung der Plattform hat gezeigt, dass die Meinung der Benutzer über die Einbeziehung dieses technologiebasierten Bildungsansatzes zufriedenstellend ist.

Chapter I. Introduction, objectives and structure of the thesis

Chapter I. Introduction, objectives and structure of the thesis

I.1. Introduction

I.2. Tuberculosis and other airborne pathogens

The importance of air as a vector for infections is often overestimated, sine only a few diseases such as open pulmonary tuberculosis, aspergillosis, measles, chickenpox and herpes zoster are classified as aerogenically transmissible[1,2]. The two different transmission mechanisms, the droplet infection and airborne infection are often confused. In fat, the droplet nuclei are residuals of small droplets that are released into the air by sneezing, coughing or speaking. Smallest droplets are able to float in the air for a long time. While they only sediment slowly, the outer water shell can evaporate (aerosol formation)[3,4].The issue with these pathogens is that the main of entrance is the airway, which allows a fast spread and the symptoms take time to manifest in the individual infected [2,5].

Among the airborne pathogens with high risk of contagious and chronic capacity highlight Tuberculosis (TB)[6]. Tuberculosis is a bacteria pulmonary infection caused by the *Mycobacterium tuberculosis*, which can be in a latent state and can take decades to be manifested. In fact, the tuberculosis is one of the main cause of death from an infectious disease, lacking in most case any symptomatology which is known as latent tuberculosis (LTB) [7,8].The pathogen is almost exclusively transmitted from person to person by tiny droplets containing, which after infecting the pulmonary tissue can hematogenous spread to the rest of the systems, such as central nervous systems, compromising the immunity of the individual affected by the bacteria[6,9]. The infection involves the presence of latent bacilli in the pulmonary parenchyma of the recipient, so that those infected without disease remain asymptomatic, presenting as the only evidence a positive tuberculinic reaction (PPD+)[3,5]. This reaction translates into the existence of a cell-mediated immune response, which is established between 2 and 12 weeks after infection, and that in 85-90% of those infected, it manages to contain multiplication of the bacillus and the development of the disease[10].

This disease is globally presented, although the region with higher prevalence are Asia and Africa, where from 60% to 90% of the population suffer from TB or LTB. In addition, these regions have more risk factors, such as silica dust or cigarette smoke, which increase the possibility of developing the disease. For example, only in China alone it is estimated that there are 320 millions of smokers and with one of the worst air pollution, the risk of developing TB is higher by approximately three percent [9]. In this sense, it is estimated that up to 1.2 million people died in

2018, which represents a number of deaths higher than desired. Despite the mobility, the rate of comorbidity continues in decrease in the world, but in high-income countries the rate is more fluctuant since the migratory flows, the screening capacity or the vaccination[11–13].

Among the individuals with higher risk of exposure to airborne pathogens, such as Covid-19, and tuberculosis, healthcare workers highlight as a group with high prevalence, constant and training to prevent exposure[14–16]. Healthcare workers are at risk to be infected by many different biological pathogens, which include the human immunodeficiency virus (HIV), the hepatitis B virus, tuberculosis and the latest the sars-covid-2 and later disease Covid-19[2,17,18]. In this population, the rate of work-related accidents and illnesses is around 3.2 per cent, being this rate is variable and dependant of a on a number of factors, such as continues training, the personal protective equipment, the actions taken by the worker and the effectiveness of the preventive interventions[19–21]. Airborne pathogens and mild infectious illnesses like tuberculosis are extremely contagious and can cause severe impacts on healthcare workers [22]. The symptoms of these diseases take time to appear, which can prevent workers from noticing that they have been exposed until symptoms are evident [5,23]. In fact, the World Health organization (WHO) stated prior to the pandemic the great risk of the airborne pathogens for populations and healthcare systems, based on the capacity of spread, promoting the training and the reinforming of the structure[24].

In the case of tuberculosis, the public concern is based on the prevalence of the general population and health workers suffering from the disease[25]. A WHO report estimated in 2015 that up to two billion people worldwide suffer from a latent state of tuberculosis [26], which remains worryingly prevalent in low-risk countries such as Italy [27,28]. In Italy, 2.1% of health workers were diagnosed with latent TB infections in 2015 [25]. Similar results were found in a previous systematic review which detailed that 2.9% of health workers in low incidence countries had latent TB [29].

Many factors can contribute to accidental exposure to TB or other biological agents, although the main factors remain lack of experience, skills or knowledge in handling materials, and anxiety, fatigue and lack of care for oneself or other professionals[8,30]. An example would the burnout, which is a risk factor for developing mental and physical disorders, but also increase the probability of having a contact with an object contaminated [31]. In the case of TB, lack of knowledge about transmission, relevant preventive and biosecurity measures and diagnosis of the disease appear to play an important role [32]. In addition, the current situation with the new pandemic has highlighted the lack of professional and personal protective equipment (PPE) and adequate training in hospitals, which could have a major impact on the prevention of airborne

pathogens [33]. In addition, recent studies have highlighted the need to develop guidelines and training programmes for university students and health professionals, especially for tuberculosis and other airborne pathogens [34]. In this regard, several studies have highlighted the importance of ensuring that health workers receive training and have control measures in place, although these activities are difficult to implement [35,36].

I.3. Safety culture and safety

Safety culture is a term originated in 1988 and initially applied to the other sciences, rapidly switched to the health field, turning into a concept around the patient care and organizational structure [37,38]. This term can be defined as the product of the combination of an individual or group values, attitudes, competencies and patterns of behaviour that determine the structure, actions or organization of the system[39]. Most articles have focused on structural improvements to prevent accidents, like falls, but the measures taken to decrease the exposure to biological agents sometimes forget the workers opinion, knowledge, training or their participation as end users[40,41].

In the healthcare systems, safety culture focused more on the organization or the patient for treatment and follow-up, the workers are often forgotten [39,42]. In the case of the organization, measures have been taken methods to manage hazardous situations and risks [42,43]. Safety culture in the healthcare system can be defined as the shared values among healthcare workers depending on the relevance given by these groups and has a main function for health and safety measures in different areas of work [42]. An example of this is the hygiene and hand washing which is a main asset in the patient care and prevention of complications for workers and patients, but that continues to have some resistance depending on the importance given by the workers[44,45]. This perception plays a key role to prevent accidents, for instance, a study carried out in Canada showed that nurses and other practitioners indicated poor opinion regarding safety climate, especially the lack of PPE [41]. This study showed that the opinion, integration and training of healthcare workers counite to be deficient. In the case of training and education, both initial and continuing training of their health care personnel needs improvement, including their point of view, adapting to the needs of the workers and the changes of the environment, all of it to prevent biological accidents and exposure to pathogens [46]. Despite changes and inclusion of initial and continuing training over more than two decades, the level of information and fulfilment with universal precautionary procedures remains inadequate [44,45]. Therefore,

there is a need to improve the training and precautions via increasing the safety culture among healthcare workers[38].

I.4. Occupational safety and health among healthcare workers

After the industrial revolution, the first efforts to control environmental factors such as production appeared. This period conformed the concept known now as Occupational Safety and Health (OSH). Although the first time that biological agents were first identified and defined was in 18th century and since then different countries have developed methods to prevent and control outbreaks. It was in England, during the industrial revolution, that the first measures were taken to control the outbreaks from TB, cholera and other diseases [47]. Later on, other countries began to develop methods to control pathogens among their populations, such as Spain, which from the beginning of the 20th century attempted to control the Spanish flu[48]. However, it was only when the World Health Organization (WHO) highlighted the need for a range of pathogen control measures to ensure the health of the working population in 1985 that these methods were included and applied in workplaces[49,50].

OSH has been defined by the WHO as the field focused on the complete physical, mental and social well-being of the workers, allowing an individual performance correctly their role or occupancy, preventing any harm for their health or reducing such harm[51,52]. It aligns with the promotion of health and safety at work, which is concerned with preventing harm from hazards in the workplace, employees and employers in the health service have to take further measures to reduce the risk in the environment[28]. These employees have an increased risk of infection due to their activities[53], since these workers affected by an infectious disease, an infection can have serious and sometimes fatal consequences [40,47]. The few, but sometimes severe, courses of disease in infections with multi-resistant pathogens indicate that more attention must be paid to the occupational risk of infection by these pathogens[55]. Among the pathogens that are multi-resistant, the multi-resistant tuberculosis has more side effects based on the time, chronicity and reduced of the treatment [55,56]. In this sese, half a million multidrug-resistant tuberculosis cases were estimated around the world, being extensively drug-resistant tuberculosis, which defined resistant to second-line drug, is now prevalent in over 45 countries. However, due to a lack of laboratory capacities and/or insufficient data collection, the correct assessment of the situation is difficult[21,29,57] . The problem is primarily a consequence of treatment errors, the causes of which are manifold but theoretically avoidable, but because of the weaknesses or the lack of diagnostic and therapeutic options, many countries the situation has been overcomplicated[58].

Only rapid and internationally concerted action combined with increased research efforts as well as support to affected countries will save from a situation that can no longer be managed even with 21st century resources[59]. But on the positive side, staff from the healthcare system only have an increased risk of tuberculosis in certain situations, which can be reduced by observing hygiene measure[60]. Nevertheless, several studies have highlight that the technicians or workers in direct contact with *Mycobacterium Tuberculosis* in the laboratories or the nurses in direct contact with infected patients have higher prevalence of LTB and higher risk than other healthcare workers[61,62]. In the case of the workers of the laboratories, whether integrated or not in hospital, there is a lack of studies regarding the knowledge, measures taken by workers, training and preventing measures[63].Therefore, regular screening examinations for tuberculosis by the healthcare workers and the conditions of the working environment must be provided for all employees in special areas of activity[64,65].

I.5. New communication and information technology

Since the 1980s, technological tools have changed the way people interact with their environment [66]. In fact, information and communication technologies (ICTs), which include digital and analogue substructures, the gears and devices; enable workers and institutions the trade of data and analysis almost in real time[67]. These technologies had as breaking point the 1990s, which coincide with the incorporation of the Internet and the establishment of the digital age, which resulted in the incorporation of the ICT in organizations and systems [68]. Simultaneously, OSH measures have been included the integration of the ICTs in working environment and health of the workers, mainly because of the recommendations made by WHO in recent years [69,70]. Many countries around the world, like United States (US) or United Kingdom (UK), in various structures around from industries to health care systems for workers and consumers, have included, integrated or developed guidelines and protocols using as central pillar the ICTs[71]. This rapid growth and insertion of ICTs has been greeted as an unprecedented chance to address growing concerns, especially in the area of health and in prevention [66].

In this sense, the European Agency for Safety and Health at Work considers that information and communication technologies are the main methods to achieve the goals proposed to improve working life and the dissemination of good practices[72]. And workers shall be informed of any health and safety measures taken and shall receive sufficient and appropriate training and accurate information based on all available data. In this way, awareness raising and staff training on risk groups, sources of infection and protective measures are important tools in the fight

against Tuberculosis. In fact, an example in the field of preventing TB has been made by the WHO, which created a web-based platform to control and prevent the spread of TB[73].

Objectives

This international dissertation, which was framed in a funding project and recived a grant to carry out an international research stay, had as main objective the examination of the relationship between the exposure to tuberculosis, the condition of the healthcare workers and the integration or use of ICTs (O1, O2, O3, O5, O6). And other objectives in a secondary level was to measure the ventilation of laboratories as preventive method (O4). Finally, the last objective was to determine the difference regarding prevention among countries in the European Union (O7) These objectives and hypothesis have been achieved and tested in chapters of this thesis and being chapter II, III and V published articles in Open Access and subscribed access.

O1: Determination of the link between ICTs, occupational safety and pathogens.

O2: Analysis of the workers in mycobacteriology laboratories in the European Union and other areas complaince with the regulations on safety and health at work.

O3: Estimation of the protective grade in healthcare staff against the risks related to exposure to biological agents at work.

O4: Measurement of the ventilation necessary for certain exposures in spaces such as laboratories, primary care clinics or emergency centers.

O5: Evaluation, design and implementation of a Virtual Laboratory (VL) for the training of workers know that are exposed to risks.

O6: Preparation of safety data sheets for Mycobacteria that provide useful information to personnel working with these agents.

O7: Comparison of the guidelines or preventive protocols from Germany and Spain.

Most of the objectives have been accomplished in this dissertation (O1, O2, O3 and O5), although the O4 could not be included due to the pandemic of Covid-19. The O5 and O6 have been partially achieved in Chapertes V and VI., since the Virtual Laboratory (VL) is currently been developed, Nevertheless, many of the sheets regarding safety are available in the oficial Ministeries of Spain

and Germany. The objectives achieved have been tested in chapters II, III, IV, V and VI, and have been published in open access journals:

Chapter II: Vaquero-Álvarez E, Cubero-Atienza A, Ruiz-Martínez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future. Int. J. Environ. Res. Public Health 2020, 17, 6732; doi:10.3390/ijerph17186732. IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1 (**O1**)

Chapter III: Vaquero-Álvarez E, Cubero-Atienza A, Ruiz-Martínez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Tuberculosis and Other Airborne Microbes in Occupational Health and Safety. Int. J. Environ. Res. Public Health 2020, 17, 7088; doi:10.3390/ijerph17197088. IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1 (**O2 and O3**)

Chapter V: Vaquero-Álvarez E, Cubero-Atienza A, Martínez-Jiménez P, Vaquero-Abellán M, Redel Macías MD, Aparicio-Martínez P. Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot. Int. J. Environ. Res. Public Health 2020, 17, 8381; doi:10.3390/ IF=2.849 (2019) (32/170 categoría Public Environmental & Occupational Health) Q1 (partially **O5**)

I.2. Structure

This thesis consists of six chapters, three of which are articles published in indexed journals: Chapter II III and V *International Journal of Environmental Research and Public Health*, Chapters IV and VI are under revision.

The thesi is structured as follows:

- Chapter I: Introduction, objectives, and structure of the thesis.
- Chapter II: Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future
- Chapter III: Tuberculosis and Other Airborne Microbes in Occupational Health and Safety
- Chapter IV: Preventing tuberculosis among populations and healthcare workers in Spain and Germany: a comparison of protocols

- Chapter V: Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot
- Chapter VI: Training healthcare workers using an educational technological approach: A preliminary study
- Chapter VII: Conclusions and future research

I.3. References

1. Acuña-Villaorduña, C.; White, L.; Fennelly, K.; Jones-Lopez, E. Tuberculosis transmission: Sputum vs aerosols. *The Lancet Infectious Diseases* **2016**, *16*, 770–771, doi:10.1016/S1473-3099(16)30075-5.

2. Aliabadi, A.A.; Rogak, S.N.; Bartlett, K.H.; Green, S.I. Preventing Airborne Disease Transmission: Review of Methods for Ventilation Design in Health Care Facilities. *Advances in Preventive Medicine* **2011**, *2011*, 124064, doi:10.4061/2011/124064.

3. Ather, B.; Mirza, T.M.; Edemekong, P.F. Airborne Precautions. In *StatPearls*; StatPearls Publishing: Treasure Island (FL), 2020.

4. Beggs, C.B.; Kerr, K.G.; Donnelly, J.K.; Sleigh, P.A.; Mara, D.D.; Cairns, G. An engineering approach to the control of Mycobacterium tuberculosis and other airborne pathogens: a UK hospital based pilot study. *Trans Roy Soc Trop Med Hyg* **2000**, *94*, 141–146, doi:10.1016/S0035-9203(00)90250-5.

5. Wei, J.; Li, Y. Airborne spread of infectious agents in the indoor environment. *American Journal of Infection Control* **2016**, *44*, S102–S108, doi:10.1016/j.ajic.2016.06.003.

6. Bonville, C.; Domachowske, J. Tuberculosis. In *Vaccines: A Clinical Overview and Practical Guide*; Domachowske, J., Suryadevara, M., Eds.; Springer International Publishing: Cham, 2021; pp. 363–372 ISBN 978-3-030-58414-6.

7. Frascella, B.; Richards, A.S.; Sossen, B.; Emery, J.C.; Odone, A.; Law, I.; Onozaki, I.; Esmail, H.; Houben, R.M.G.J. Subclinical tuberculosis disease - a review and analysis of prevalence surveys to inform definitions, burden, associations and screening methodology. *Clinical Infectious Diseases* **2020**, ciaa1402, doi:10.1093/cid/ciaa1402.

8. Casas, I.; Esteve, M.; Guerola, R.; García-Olivé, I.; Ruiz-Manzano, J. A Study of Tuberculosis Infection in Workers at a University General Hospital: Associated Factors and

Evolution in 20 Years. *Archivos de Bronconeumología (English Edition)* **2011**, *47*, 541–546, doi:10.1016/j.arbr.2011.07.005.

9. Byrne, A.L.; Marais, B.J.; Mitnick, C.D.; Lecca, L.; Marks, G.B. Tuberculosis and chronic respiratory disease: a systematic review. *International Journal of Infectious Diseases* **2015**, *32*, 138–146, doi:10.1016/j.ijid.2014.12.016.

10. Casas, I.; Dominguez, J.; Rodríguez, S.; Matllo, J.; Altet, N. Guía para la prevención y control de la tuberculosis en el personal sanitario. *Medicina Clínica* **2015**, *145*, 534.e1-534.e13, doi:10.1016/j.medcli.2015.06.018.

11. Basham, C.A.; Smith, S.J.; Romanowski, K.; Johnston, J.C. Cardiovascular morbidity and mortality among persons diagnosed with tuberculosis: A systematic review and meta-analysis. *PLoS ONE* **2020**, *15*, e0235821, doi:10.1371/journal.pone.0235821.

12. Boudville, D.A.; Joshi, R.; Rijkers, G.T. Migration and tuberculosis in Europe. *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases* **2020**, *18*, 100143, doi:10.1016/j.jctube.2020.100143.

13. Ködmön, C.; Zucs, P.; van der Werf, M.J. Migration-related tuberculosis: epidemiology and characteristics of tuberculosis cases originating outside the European Union and European Economic Area, 2007 to 2013. *Eurosurveillance* 2016, *21*, 30164.

14. Belingheri, M.; Paladino, M.E.; Riva, M.A. Beyond the assistance: additional exposure situations to COVID-19 for healthcare workers. *J. Hosp. Infect.* **2020**, *105*, 353, doi:10.1016/j.jhin.2020.03.033.

15. Casas, I.; Latorre, I.; Esteve, M.; Ruiz-Manzano, J.; Rodriguez, D.; Prat, C.; García-Olivé, I.; Lacoma, A.; Ausina, V.; Domínguez, J. Evaluation of Interferon-Gamma Release Assays in the Diagnosis of Recent Tuberculosis Infection in Health Care Workers. *PLoS ONE* **2009**, *4*, e6686, doi:10.1371/journal.pone.0006686.

16. Coppeta, L.; Pietroiusti, A.; Neri, A.; Janni, A.; Baldi, S.; Papa, F.; Magrini, A. Prevalence and Risk Factors for Latent Tuberculosis Infection among Healthcare Workers in a Low Incidence Country. *Open Respir Med J* **2019**, *13*, 1–4, doi:10.2174/1874306401913010001.

17. Almeida, M.C.M. de; Canini, S.R.M. da S.; Reis, R.K.; Toffano, S.E.M.; Pereira, F.M.V.; Gir, E. Clinical treatment adherence of health care workers and students exposed to potentially

infectious biological material. *Rev. Esc. Enferm. USP.* **2015**, *49*, 261–266, doi:10.1590/S0080-623420150000200011.

18. Peng, S.; Chen, Q.; Liu, E. The role of computational fluid dynamics tools on investigation of pathogen transmission: Prevention and control. *Sci Total Environ.* **2020**, *746*, 142090, doi:10.1016/j.scitotenv.2020.142090.

19. Jensen, P.A.; Lambert, L.A.; Iademarco, M.F.; Ridzon, R. Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005. *MMWR Recomm Rep* **2005**, *54*, 1–141.

20. Loveday, H.P.; Wilson, J.A.; Pratt, R.J.; Golsorkhi, M.; Tingle, A.; Bak, A.; Browne, J.; Prieto, J.; Wilcox, M. epic3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England. *J Hosp Infect.* **2014**, *86*, S1–S70, doi:10.1016/S0195-6701(13)60012-2.

21. Centers for Disease Control and Prevention (CDC) Plan to combat extensively drug-resistant tuberculosis: recommendations of the Federal Tuberculosis Task Force. *MMWR Recomm Rep* **2009**, *58*, 1–43.

22. Bahl, P.; Doolan, C.; de Silva, C.; Chughtai, A.A.; Bourouiba, L.; MacIntyre, C.R. Airborne or Droplet Precautions for Health Workers Treating Coronavirus Disease 2019? *The Journal of Infectious Diseases* **2020**, doi:10.1093/infdis/jiaa189.

23. Qian, H.; Zheng, X. Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. *J. Thorac. Dis.* **2018**, *10*, S2295–S2304, doi:10.21037/jtd.2018.01.24.

24. Global Preparedness Monitoring Board *A WORLD AT RISK. Annual report on global preparedness for health emergencies*; GPMB, 2019; p. 48;.

25. World Health Organization Incidence of tuberculosis Available online: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/incidence-of-tuberculosis-(per-100-000-population-per-year) (accessed on Dec 1, 2020).

26. World health organization *Global tuberculosis report 2019*; World health organization.: Geneva, 2019; ISBN 978-92-4-156571-4.

27. Durando, P.; Sotgiu, G.; Spigno, F.; Piccinini, M.; Mazzarello, G.; Viscoli, C.; Copello, F.; Poli, A.; Ansaldi, F.; Icardi, G. Latent tuberculosis infection and associated risk factors among

undergraduate healthcare students in Italy: a cross-sectional study. *BMC Infect Dis* **2013**, *13*, 443, doi:10.1186/1471-2334-13-443.

28. *Occupational health and safety risks in the healthcare sector: guide to prevention and good practice*; European Commission, Ed.; Social Europe; Publ. Off. of the Europ. Union: Luxembourg, 2011; ISBN 978-92-79-19454-2.

29. Abubakar, I.; Dara, M.; Manissero, D.; Zumla, A. Tackling the spread of drug-resistant tuberculosis in Europe. *The Lancet* **2012**, *379*, e21–e23, doi:10.1016/S0140-6736(11)61428-1.

30. Coppeta, L.; Pietroiusti, A.; Balbi, O.; Baldi, S. QuantiFERON-TB Gold Plus evaluation for latent tuberculosis infection among Italian healthcare workers: a cross-sectional study. **2019**, doi:10.2427/13123.

31. Hu, D.; Kong, Y.; Li, W.; Han, Q.; Zhang, X.; Zhu, L.X.; Wan, S.W.; Liu, Z.; Shen, Q.; Yang, J.; et al. Frontline nurses' burnout, anxiety, depression, and fear statuses and their associated factors during the COVID-19 outbreak in Wuhan, China: A large-scale cross-sectional study. *EClinicalMedicine* **2020**, *24*, 100424, doi:10.1016/j.eclinm.2020.100424.

32. Vaquero-Alvarez, E.; Lopez-Roldan, P.; Palomares, F.; Torralbo, F.; Casal, M.; Vaquero, M. Training in biosafety against M. Tuberculosis: experience in the Mycobacteria Reference Center at the University of Cordoba,.; Dr. Stefan Niemann: FlorenceItaly, 2013.

33. Fiabane, E.; Giorgi, I.; Sguazzin, C.; Argentero, P. Work engagement and occupational stress in nurses and other healthcare workers: the role of organisational and personal factors. *J Clin Nurs* **2013**, *22*, 2614–2624, doi:10.1111/jocn.12084.

34. Boucaut, R.; Knobben, L. Occupational health and safety incidents at a university school of nursing: A retrospective, descriptive appraisal. *Nurse Education in Practice* **2020**, *44*, 102776, doi:10.1016/j.nepr.2020.102776.

35. Bahn, S.; Barratt-Pugh, L. Emerging Issues of Health and Safety Training Delivery in Australia: Quality and Transferability. *Procedia - Social and Behavioral Sciences* **2012**, *62*, 213–222, doi:10.1016/j.sbspro.2012.09.035.

36. Kazan (Volga region) Federal University, Kazan, Russia, m iterenteva49@mail.ru; Terentyeva, I.V.; Pugacheva, N.B.; Kazan State University of Architecture and Engineering, Russia, pug4chevanat@yandex.ru; Luchinina, A.O.; Vyatka state University, Kirov, Russia, a8210@rambler.ru; Khalmetov, T.A.; Kazan Law Institute of the Ministry of Internal Affairs of the

Russian Federation, Kazan, Russia, volk-nk@mail.ru; Safin, N.M.; Kazan Law Institute of the Ministry of Internal Affairs of the Russian Federation, Kazan, Russia, akontan@mail.ru; et al. Selection and Structuring of Training Multimedia Educational Materials for University Students: Practical Recommendations. *INT J INSTRUCTION* **2019**, *12*, 759–780, doi:10.29333/iji.2019.12346a.

37. Giménez-Marín, A.; Rivas-Ruiz, F.; García-Raja, A.M.; Venta-Obaya, R.; Fusté-Ventosa, M.; Caballé-Martín, I.; Benítez-Estevez, A.; Quinteiro-García, A.I.; Bedini, J.L.; León-Justel, A.; et al. Assessment of patient safety culture in clinical laboratories in the Spanish National Health System. *Biochem Medica* **2015**, *25*, 363–376, doi:10.11613/bm.2015.036.

38. Goodman, G.R. A Fragmented Patient Safety Concept: The Structure and Culture of Safety Management in Healthcare. *null* **2003**, *81*, 22–29, doi:10.1080/00185860309598018.

39. Halligan, M.; Zecevic, A. Safety culture in healthcare: A review of concepts, dimensions, measures and progress. *BMJ quality & safety* **2011**, *20*, 338–43, doi:10.1136/bmjqs.2010.040964.

40. Yassi, A.; Lockhart, K.; Buxton, J.A.; McDonald, I. Vaccination of Health Care Workers for Influenza: Promote Safety Culture, Not Coercion. *Canadian Journal of Public Health* **2010**, *101*, S41–S45, doi:10.1007/BF03403845.

41. McGhan, G.E.; Ludlow, N.C.; Rathert, C.; McCaughey, D. Variations in Workplace Safety Climate Perceptions and Outcomes Across Healthcare Provider Positions. *Journal of Healthcare Management* **2020**, *65*.

42. Flin, R. Measuring safety culture in healthcare: A case for accurate diagnosis. *Safety Science* **2007**, *45*, 653–667, doi:10.1016/j.ssci.2007.04.003.

43. Bye, R.J.; Aalberg, A.L.; Røyrvik, J.O.D. What we talk about when we talk about HSE and culture – A mapping and analysis of the academic discourses. *Safety Science* **2020**, *129*, 104846, doi:10.1016/j.ssci.2020.104846.

44. Unakal, C.G.; Nathaniel, A.; Keagan, B.; Alexandria, B.; Lauralee, B.; Varun, C.; Reneé, D.; Sarah, D.; Uniqué, T.; Akpaka, P.E. Assessment of knowledge, attitudes, and practices towards infection prevention among healthcare workers in Trinidad and Tobago. *Int J Community Med Public Health* **2017**, *4*, 2240, doi:10.18203/2394-6040.ijcmph20172813.

45. Handiyani, H.; Meily Kurniawidjaja, L.; Irawaty, D.; Damayanti, R. The effective needle stick injury prevention strategies for nursing students in the clinical settings: a literature review. *Enfermería Clínica* **2018**, *28*, 167–171, doi:10.1016/S1130-8621(18)30060-3.

46. Corvino, A.R.; Garzillo, E.M.; Arena, P.; Cioffi, A.; Monaco, M.G.L.; Lamberti, M. Augmented Reality for Health and Safety Training Program Among Healthcare Workers: An Attempt at a Critical Review of the Literature. In Proceedings of the Human Systems Engineering and Design; Ahram, T., Karwowski, W., Taiar, R., Eds.; Springer International Publishing: Cham, 2019; pp. 711–715.

47. Szreter, S. Industrialization and health. *British Medical Bulletin* **2004**, *69*, 75–86, doi:10.1093/bmb/ldh005.

48. Papadopoulos, G.; Georgiadou, P.; Papazoglou, C.; Michaliou, K. Occupational and public health and safety in a changing work environment: An integrated approach for risk assessment and prevention. *Saf. Sci.* **2010**, *48*, 943–949, doi:10.1016/j.ssci.2009.11.002.

49. Aljabri, D.; Vaughn, A.; Austin, M.; White, L.; Li, Z.; Naessens, J.; Spaulding, A. An Investigation of Healthcare Worker Perception of Their Workplace Safety and Incidence of Injury. *Workplace Health Saf* **2020**, *68*, 214–225, doi:10.1177/2165079919883293.

50. Harrison, J. Occupational Safety and Health in The United Kingdom: Securing Future Workplace Health and Wellbeing. *Ind. Health* **2012**, *50*, 261–266, doi:10.2486/indhealth.MS1376.

51. Bilir, S.; Ghavam, E.; Sancak, L. The Comparison of Occupational Health and Safety Legislation of Different Countries from the View of Inspection.; The XXVI th Annual Occupational Ergonomics and Safety Conference: El Paso, TX, USA, 2014; p. 7.

52. Badri, A.; Boudreau-Trudel, B.; Souissi, A.S. Occupational health and safety in the industry 4.0 era: A cause for major concern? *Saf Sci* **2018**, *109*, 403–411, doi:10.1016/j.ssci.2018.06.012.

53. de Vries, G.; Sebek, M.M.G.G.; Lambregts-van Weezenbeek, C.S.B. Healthcare workers with tuberculosis infected during work. *Eur Respir J* **2006**, *28*, 1216–1221, doi:10.1183/09031936.06.00039906.

54. Diel, R.; Loytved, G.; Nienhaus, A.; Castell, S.; Detjen, A.; Geerdes-Fenge, H.; Haas, W.; Hauer, B.; Königstein, B.; Maffei, D.; et al. Neue Empfehlungen für die Umgebungsuntersuchungen bei Tuberkulose. *Pneumologie* **2011**, *65*, 359–378, doi:10.1055/s-0030-1256439.

55. Heyckendorf, J.; van Leth, F.; Avsar, K.; Glattki, G.; Günther, G.; Kalsdorf, B.; Müller, M.; Olaru, I.; Rolling, T.; Salzer, H.; et al. Treatment responses in multidrug-resistant tuberculosis in

Germany. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease* **2018**, *22*, 399—406, doi:10.5588/ijtld.17.0741.

56. DuRant, R.H.; Smith, J.A.; Kreiter, S.R.; Krowchuk, D.P. The Relationship Between Early Age of Onset of Initial Substance Use and Engaging in Multiple Health Risk Behaviors Among Young Adolescents. *Archives of Pediatrics & Adolescent Medicine* **1999**, *153*, 286–291, doi:10.1001/archpedi.153.3.286.

57. Loddenkemper, R.; Hauer, B. Drug Resistant Tuberculosis. *Deutsches Aerzteblatt Online* **2010**, doi:10.3238/arztebl.2010.0010.

58. Parsons, L.M.; Somoskövi, Á.; Gutierrez, C.; Lee, E.; Paramasivan, C.N.; Abimiku, A.; Spector, S.; Roscigno, G.; Nkengasong, J. Laboratory Diagnosis of Tuberculosis in Resource-Poor Countries: Challenges and Opportunities. *Clin. Microbiol. Rev.* **2011**, *24*, 314, doi:10.1128/CMR.00059-10.

59. Ridderhof, J.C.; van Deun, A.; Kam, K.M.; Narayanan, P.R.; Aziz, M.A. Roles of laboratories and laboratory systems in effective tuberculosis programmes. *Bull World Health Organ* **2007**, *85*, 354–359, doi:10.2471/blt.06.039081.

60. Sopjani, I.; Jahn, P.; Behrens, J. Training as an Effective Tool to Increase the Knowledge About Hand Hygiene Actions. An Evaluation Study of Training Effectiveness in Kosovo. *Med Arch* **2017**, *71*, 16–19, doi:10.5455/medarh.2017.71.16-19.

61. Shinnick, T.M.; Iademarco, M.F.; Ridderhof, J.C. National plan for reliable tuberculosis laboratory services using a systems approach. Recommendations from CDC and the Association of Public Health Laboratories Task Force on Tuberculosis Laboratory Services. *MMWR Recomm Rep* **2005**, *54*, 1–12.

62. Nasehi, M.; Hashemi-Shahraki, A.; Doosti-Irani, A.; Sharafi, S.; Mostafavi, E. Prevalence of latent tuberculosis infection among tuberculosis laboratory workers in Iran. *Epidemiol Health* **2016**, *39*, e2017002–e2017002, doi:10.4178/epih.e2017002.

63. Garnett, J.; Jones, D.; Chin, G.; Spiegel, J.M.; Yassi, A.; Naicker, N. Occupational Tuberculosis Among Laboratory Workers in South Africa: Applying a Surveillance System to Strengthen Prevention and Control. *IJERPH* **2020**, *17*, 1462, doi:10.3390/ijerph17051462.

64. Schablon, A.; Nienhaus, A.; Ringshausen, F.; Preisser, A.; Peters, C. Occupational Screening for Tuberculosis and the Use of a Borderline Zone for Interpretation of the IGRA in German Healthcare Workers. *PLoS ONE* **2014**, *9*, e115322, doi:10.1371/journal.pone.0115322.

65. Slater, M.L.; Welland, G.; Pai, M.; Parsonnet, J.; Banaei, N. Challenges with QuantiFERON-TB Gold Assay for Large-Scale, Routine Screening of U.S. Healthcare Workers. *Am J Respir Crit Care Med* **2013**, *188*, 1005–1010, doi:10.1164/rccm.201305-0831OC.

66. Abu-elezz, I.; Hassan, A.; Nazeemudeen, A.; Househ, M.; Abd-alrazaq, A. The benefits and threats of blockchain technology in healthcare: A scoping review. *Int J Med Inform* **2020**, 104246, doi:10.1016/j.ijmedinf.2020.104246.

67. E. Mattila; J. Koskelo; R. Lappalainen; J. Salminen; P. Nyman; J. Lahteenmaki; T. Leino; I. Korhonen A Concept for ICT Assisted Health Promotion in the Occupational Healthcare. In Proceedings of the 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2007; pp. 1786–1789.

68. The Internet Information and Technology Research Directions based on the Fourth Industrial Revolution. *KSII TIIS* **2016**, *10*, doi:10.3837/tiis.2016.03.020.

69. Schaper, L.K.; Pervan, G.P. ICT and OTs: A model of information and communication technology acceptance and utilisation by occupational therapists. *International Journal of Medical Informatics* **2007**, *76*, S212–S221, doi:10.1016/j.ijmedinf.2006.05.028.

70. Rubio-Romero, J.C.; Arquillos, A.; Suárez-Cebador, M.; Carrillo-Castrillo, J. Information and Communication Technologies (ICT) in Occupational Health and Safety (OHS) courses at engineering under/degree studies. In *Occupational Safety and Hygiene*; CRC Press, 2014; pp. 49–52 ISBN 978-1-138-00144-2.

71. European Agency for Safety and Health at Work.; TC OSH. *Priorities for occupational safety and health research in Europe: 2013 2020.*; Publications Office of the European Union: Luxembourg, 2013;

72. Verra, S.E.; Benzerga, A.; Jiao, B.; Ruggeri, K. Health Promotion at Work: A Comparison of Policy and Practice Across Europe. *Saf. Health Work* **2019**, *10*, 21–29, doi:10.1016/j.shaw.2018.07.003.

73. World Health Organization Prevent TB Digital Platform Available online: https://www.who.int/tb/prevent-tb-digital-platform/en/ (accessed on Dec 14, 2020).

Chapter II. Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future

Chapter II. Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], Pilar Ruiz-Martínez [3], Manuel Vaquero-Abellán [4,5], María Dolores Redel Mecías [2] and Pilar Aparicio-Martínez [4,5,*]

[1] SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de

[2] Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C-A.);ig1 remam@uco.es (M.D.R.M.)

[3] GC24 Clinical and Molecular Microbiology, Instituto Maimónides, Facultad Medicina y Enfermería, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; mi1 rumap@uco.es;

[4] GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; n32apmap@uco.es (P.A-M); en1vaabm@uco.es (M.V-A.)

[5] departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, 14071 Córdoba, Spain; n32apmap@uco.es (P.A-M); en1vaabm@uco.es (M.V-A.)

Abstract: Since the eighties, technological tools have modified how people interact in their environment. At the same time, occupational safety and health measures have been widely applied. The European Agency for Safety and Health at Work considers that information and communication technologies are the main methods to achieve the goals proposed to improve working life and the dissemination of good practices. The principal objective was to determine the trends of publications focused on these technologies and occupational safety in the healthcare sector during the last 30 years. A bibliometric study was carried out. The 1021 documents showed an increased trend per country, especially for the United States ($p < 0.001$) and year ($p < 0.001$). The citations per year showed significant differences between citations of articles published before 2007 ($p < 0.001$). The year was also linked to the increase or decrease of articles (72.2%) and reviews (14.9%) ($p < 0.001$). The analysis of journal co-citations also showed that the main journals (such as Infection Control and Hospital Epidemiology) were linked to other important journals and had a major part in the clusters formed. All these findings were discussed in the manuscript and conclusions were drawn.

Keywords: healthcare workers; ICTs; occupational health; scientometric analysis

II.1. Introduction

Since the eighties, technological tools have modified how people interact with their environment [1]. At the same time, occupational safety and health (OSH) measures were widely applied due to the recommendation of the World Health Organization (WHO) regarding the health and working environment [2]. Both changes facilitated the inclusion of information and communication

technologies (ICTs) in the working environment [3]. Numerous countries, such as the United States (US) or the United Kingdom (UK), included information and communication technologies (ICTs) in several structures from industries to healthcare systems for workers and consumers [4–6].

Following the technological growth in the last decade, multiple ICTs, digital and analog substructure, gears, and widgets [7] have been created to improve the health of the populations and control risks in the environment [8,9]. In this sense, one of the main points for creating ICTs has been the development of different structures to improve the accessibility and sharing of information [9–11]. Among these new technologies, smartphones, computers, or tablets have become the favorite tools to access or exchange information[12–14]. This preference is based on their ubiquitous, easy-to-use nature and fast features [15]. Nevertheless, the use of ICTs in the workplace could be described as both favorable and unfavorable. Positively, when robotics and other technological advances are effectively used, hazards can be reduced, and training can improve [16]. However, when these technologies are misused, these tools can introduce new dangers and impact the psychosocial health of workers [17,18]. In this sense, several studies have analyzed the influence of ICTs on workers' health, highlighting mental stress or burnout syndrome, muscular problems and audio-visual alterations, and even addiction [19,20]. Nevertheless, the impact that technology has in any area is partially determined by the creator's desire or intention, and the impact of ICT depends on the user's profile and reason for utilizing such technology[21].

Despite the negative effect, European organizations, especially the European Agency for Safety and Health at Work, consider that ICTs are the primary method to achieve the goals proposed to improve working life and disseminate good practices [16]. Nevertheless, the different analyses indicated that the ICTs were not entirely integrated into occupational health and that depending on the sector, the actions of the OSH focused on one area [22,23]. An example would be that financial and scientific sectors focused on psychosocial prevention and health promotion activities, in which ICTs focused on control or training, mainly in industrial environments [24,25]. Meanwhile, the social and health sector was also more likely to promote health in the workplace, with a particular interest in promoting healthy lifestyles [22]. These results are highly contradictory since the health sector workers are more exposed to psychosocial problems, such as burnout syndrome, musculoskeletal disorders, and biological accidents [26–29]. Different reviews have shown how ICTs, especially websites or databases, could decrease these risks and promote a healthier working environment [30,31]. However, it seems that the latest ICTs created mainly focused on improving structures, surgical approaches, or treatments for patients [32,33]. Even though healthcare workers are at high risk of suffering from a disease or accident, their working environment is up against constant changes and depends on the needs of the population [31,34]. The ICTs could be applied to increase prevention knowledge and skills, changing the environment to improve workers' well-being and optimize

prevention through adequate human and material resources [35]. In fact, previous studies have stated different benefits of ICTs in the occupational health in healthcare sector from continuous training to productivity improvements [36,37]. The most outstanding benefits have been increasing efficiency, reducing errors and improving integration of best practice into routine care [36]. Currently, the ICTs in OHS seem to focus on improving clinical information systems, personal digital assistants or keeping health records of personnel [38]. Nevertheless, the analysis of previous works as a vital step in research is essential [39,40]; therefore, it is imperative to determine the previous knowledge and current tendencies in this scientific field.

Based on this, the principal objective of the current study was to determine the trends of publications focused on ICTs and occupational safety and health in the healthcare sector during the last 30 years (from 1989 to 2019). Additionally, the second objective was to determine the major sub-topics regarding the use of ICTs in occupational safety in the healthcare sector. The purpose of these objectives was to understand ICTs and OSH's interaction better to assist the decision-making of health professionals and contribute to effective prevention.

II.2. Materials and Methods

II.2.1. Design of the Study

A bibliometric study was carried out to analyze the data regarding the inclusion, use, or implementations of ICTs as an occupational safety measure for healthcare workers. The data focused on the year of publication, country, affiliation, authors id, citations, index keywords, and journal.

II.2.2. Database Selection

Before the use of the research strategy and the analysis of the data, exploratory research was carried out to select the adequate database for the objectives and study proposed. The exploratory research included diverse Medical Subject Heading (MeSH) ("technology" combined with "occupational safety", "workers") and several databases (Web of Science, Scopus, PubMed, the Health and Medical Collection, and the Psychology Database). These databases were selected based on their relevance and global use in the health field. The results of the databases were compared to determine the selection of the database for the research strategy. The exclusion criteria were the period of time from 1989 to 2019 and papers with no scientific relevance such as news, obituaries, projects, or patents, available in journals.

The research strategy (ALL = ("technology" AND "occupational safety" AND "workers")) showed different results for Web of Science (428 documents), Scopus (9479 documents), PubMed (553 documents), the Health and Medical Collection (15,418 documents), and the Psychology Database (14,568 documents). These results displayed a similar number of documents for Web of Sciences and

PubMed, higher number of documents for Scopus, and the Health and Medical Collection and Psychology Database had the highest quantity. However, the Health and Medical Collection and Psychology Database also included greater number of grey data than the other three databases (Web of Science, Scopus and PubMed). The significant difference between these databases was the theme and topic of the research, therefore, the main two databases were Web of Sciences and Scopus. The documents obtained using Scopus included the largest abstracts and citations in the field of study. This database has over 16,000 peer-reviewed journals, conference proceedings, trade publications, book series and patents, offering the widest coverage available for scientific, technical, medical and social sciences [41]. Only one database was selected based on the coverage of the topic and the objective, and the fact that previous research indicated how Web of Science and Scopus have high similarities [42]. Based on previous research and the results obtained, it was decided to choose Scopus (Elsevier's database) since it was the major database focused on the topic [43,44], providing necessary information for the quantitative analysis. Additionally, to avoid Scopus' problems with the differentiation between authors of the same name, the data have been manually revised and later checked with the authors' information.

II.2.3. Data Collection

The data were retrieved in June of 2020 from the Scopus database. After obtaining all the data, the information was saved in an Excel sheet, using Excel version 17, with a .csv format, to be later analyzed in SPSS (IBM Corporation, Armonk, NY, USA) program version 25.

Based on an initial analysis, the research strategy included more MeSH terms (Table 1). The main terms were "technology", "occupational health" and "healthcare personnel". Other terms, such as "healthcare workers", related to the MeSH terms (Table 1), were also included in the search to extract more data. The Boolean operators used were "OR" and "AND", and the fields were "title", "abstract", and "keywords".

Table 1. MeSH (Medical Subject Heading) terms and description.

Mesh Terms	Description	Related Terms
Technology	The application of scientific knowledge to practical purposes in any field. It includes methods, techniques, and instrumentation.	None
Education distance	Education via communication media (correspondence, radio, television, computer networks) with little or no in-person face-to-face contact between students and teachers.	Distance Education Distance Learning Learning, Distance Online Learning Learning, Online Online Education Education, Online Online Educations Correspondence Courses Correspondence Course Course, Correspondence
Occupational health	The promotion and maintenance of physical and mental health in the work environment.	Health, Occupational Industrial Hygiene Hygiene, Industrial Industrial Health Health, Industrial Safety, Occupational Occupational Safety Employee Health Health, Employee
Health Personnel	Men and women working in the provision of health services, whether as individual practitioners or employees of health	Personnel, Health

	institutions and programs, whether or not professionally trained, and whether or not subject to public regulation.	Health Care Providers Health Care Provider Provider, Health Care Providers, Health Care Healthcare Providers Healthcare Provider Provider, Healthcare Providers, Healthcare Healthcare Workers Healthcare Worker

II.2.4. Exclusion and Inclusion Criteria

The inclusion criteria used for this study focused on terms related to the topic such as "workers" or "professionals", "technology", and "healthcare" to determine the link between ICTs in occupational health. With the results from the terms "occupational health" or "occupational safety" and "education", it was estimated that the prevention and promotion of a healthy environment were included. Additionally, "mobile" or "mobile applications" terms were used to identify this specific tool, which is more commonly used to determine implications and find previous studies in which the tool or specific applications were developed or analyzed. The Boolean operators used were "OR" and "AND" to link the terms. Additionally, the inclusion criteria regarding the type of document focused on articles, reviews, conference papers, chapters of books, books, editorial and letters. The main language was English, although other languages with their roots based on Latin, such as Spanish, Portuguese, French or Italian, and other Indo-European languages and Uralic languages, i.e., German or Hungarian, were also included.

The exclusion criteria used were the period for the production of the documents (eliminating those documents published before 1989 and after 2019), articles focused on patients, the study

focused on workers from other sectors, such as mining, and lack of ICTs' role. Additionally, the type of document was determined in order to exclude non-scientific productions, such as projects.

II.2.5. Research Strategy

The search strategy to gather the data used the different terms and steps (Figure 1), as follows:

1 Identification: in this step, the terms were chosen and the Boolean operators "AND" and "OR" were used. The search query was the following: (TITLE-ABS-KEY (technology OR "social media" OR "Mobile applications" OR "Education, Distance") AND TITLE-ABS-KEY ("occupational health" OR "occupational safety") AND TITLE-ABS-KEY ("Health Personnel")) OR (TITLE-ABS-KEY (technology) OR TITLE-ABS-KEY ("social media") OR TITLE-ABS-KEY (mobile) OR TITLE-ABS-KEY ("e-learning") OR ABS ("e-learning") OR TITLE-ABS-KEY (online)) AND (TITLE-ABS-KEY (health) OR (TITLE-ABS-KEY ("occupational safety")) OR (TITLE-ABS-KEY ("healthcare workers"))) AND (TITLE-ABS-KEY (prevention) OR TITLE-ABS-KEY (safeguard)). This strategy was developed to identify the number of published items in which title, abstract, or keywords were included the terms (N = 23,135).

2 Screening: A total of 12,635 documents were excluded based on the timeframe and the population of the study, which were workers in other sectors or patients using the filters from the Scopus database. Later on, an additional 8627 documents were eliminated from the data based on their use of keywords in their titles or abstracts.

3 Eligibility: In this step, the abstract or the full document of the remaining 1875 documents were read to determine the main subject of the study. In this step, 852 documents were excluded from the final sample since they focused on disease transmission, such as HIV, or patients' opinions regarding the worker health or tasks.

4 Included: In this final step, 1021 documents were included for the quantitative and qualitative analysis of the data.

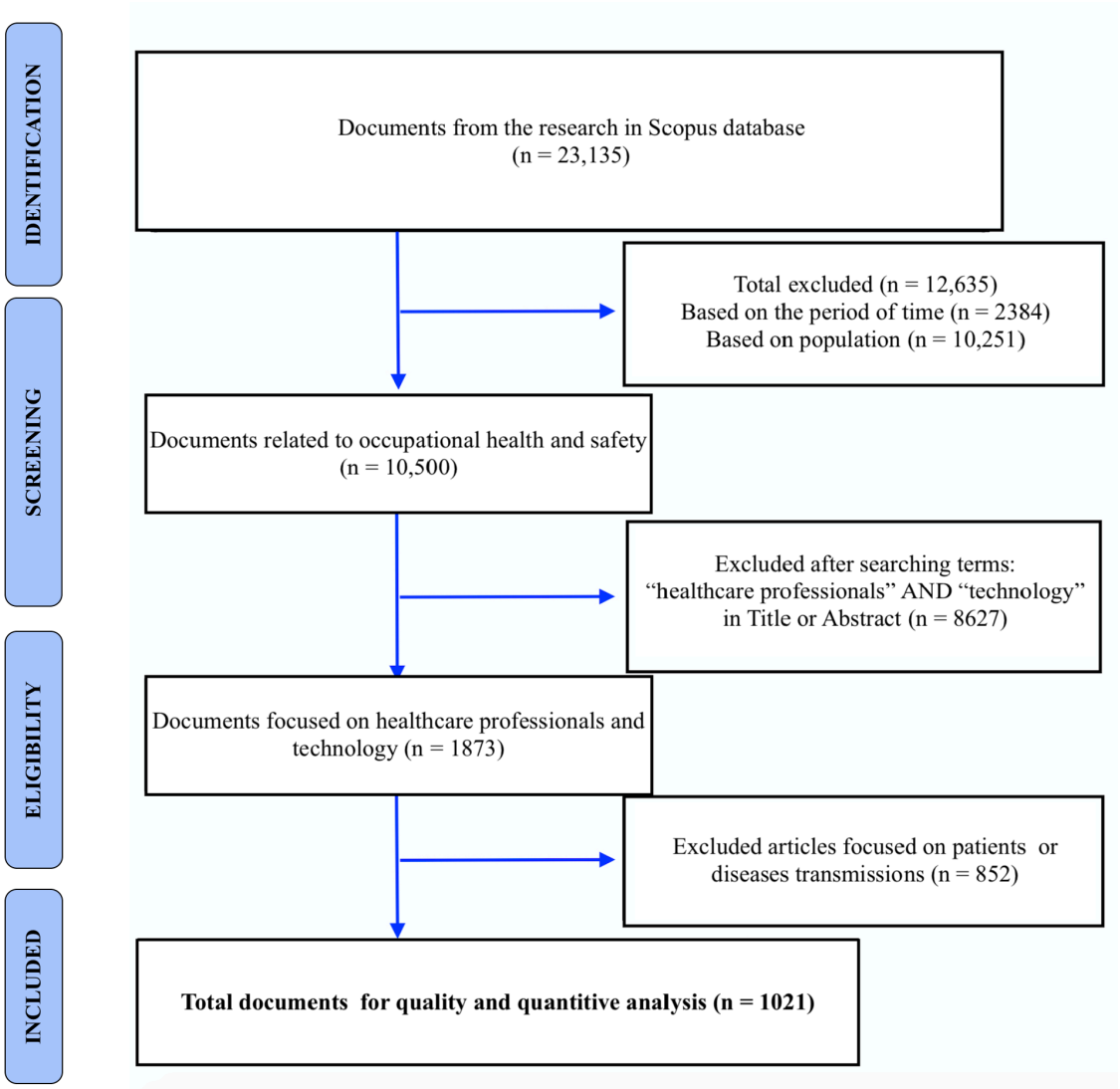


Figure 1. Flow diagram of the selection of articles for the quantitative and qualitative analysis

II.2.6. Analysis Technics and Statistical Analysis

The analysis technics used were both quantitative and qualitative. The techniques focused on counting the number of papers linked to countries, institutions and authors, and the counting of citations. Furthermore, the impact of published work on the topic was analyzed using the Journal Citation Report (JCR) and the quartile (Q1) to present the importance and relevance of the major journals. The Journal Citation Report is based on citations compiled from the Science Citation Index Expanded and the Social Sciences Citation Index and the quartiles based on ranking each journal according to their subject, using the impact factor distribution the journal occupies for that subject category as a measure [45]. The citation weighting depends on the subject field and the prestige of the citing serial. The counting of co-occurrence between authors and countries was also determined. Additionally, techniques for visualizing scientific variables (co-occurrence of keywords, countries and authors) were used via VOSviewer [46], an open-source program, as a method of

multidimensional analysis. The identification of networks using the VOSviewer software version 1.6.15 [46] was carried out to examine and create bibliometric maps [47]. The networks identified focused on co-occurrence of countries and keywords. Additionally, the co-occurrence of the authors based on the citations was carried out. The criteria used to create the maps were a minimum of five connections between countries and a maximum of fifteen countries per document. The strategy was a minimum of five connections and a maximum of ten for the co-occurrence of keywords, eliminating the term "human/s" to avoid discrepancies. The criteria used for the co-citation was the cited author and journals, with a minimum of 20 citations per author.

The results from the research were analyzed, initially using descriptive analysis, such as the frequencies of documents per country and year, the language, primary sources, the field of the publication, the leading scientific institutions, associations among nations, the primary authors in the area, and the index keywords used. Additionally, the descriptive analysis was carried out focusing on relative frequencies, mean, standard deviation (SD), median and confidence intervals (CI) 95%. To carry out the frequencies and relative analysis, and later statistical analysis, Excel (Microsoft, Redmond, WA, USA) version 2017, Numbers and SPSS (IBM Corporation, Armonk, NY, USA) version 25 were used.

Previous to the statistical analysis, the Kolmogorov–Smirnov test was applied to determine the normalization in the sample. The results of this test ($p < 0.001$) suggested that variables (year of publication, citations or number of documents per country) did not follow a normal distribution in the entire sample. Based on these results, the non-parametric tests (Chi-square, Kruskal–Wallis, and Mann–Whitney U test) and the correlation test (Spearman's correlation test) were used for the different variables. Additionally, Cramer's V test was used to determine the magnitude of the differences, such as statistics to determine the size of the effect. The variables analyzed were year of publication, country, language, type of document, keywords, citations, references (co-citations), author's id, JCR and quartile. The chi-square one test was used to determine if there were differences among the sample for the year of publication, journal, keywords used, language, type of journal and country. Based on the results obtained, the sample was divided and compared by language (English and non-English), country (US and other countries), the type of document (articles compared to reviews; and articles compared to the other documents) and the period of publication (before 2017 and after 2017). The chi-square was used for comparing countries (US and other countries) and language (English and non-English) to having or not having citations. The Mann–Whitney test was used to compare the country (US and other countries) according to the number of publications and citations per country, ranking the countries based on citations and number of documents. The Kruskal–Wallis test was used for the variables: year, citations, JCR and score of the journals. The test associated the different subgroups inside the sample, comparing the year (before 2000, before 2017

and after 2017), the number of citations (less than 100, less than 175 and less than 400) and score of journals using the quartile between the variables and with other variables, such as type of documents ranked based on the number (from articles to conference papers) or languages. The Spearman's rank correlation coefficient was used to determine associations between the countries, year of publication, language, type of documents and citations.

II.3. Results

II.3.1. Characteristics of Documents: Publication Trend and Language

The 1021 documents, focused on ICTs in occupational safety and health of healthcare workers, showed an exponential trend of publications per year for this timeframe (Figure 2). The frequency of production per year increased from 1989 (0.29%) to 2019 (13.22%), although depending on the years the number and frequency of publication changes. However, the increase has not been linear and there have been some fluctuations, decreasing the number of publications in a time frame (from in 2005, in which 23 documents were published, to 2009, with 22 documents). The exponential trendline (Figure 2) showed that the trend of publications followed a growth at a progressively higher rate, based on R-squared value close to 1. This result showed that the line almost fit the data perfectly. In this sense, the number of documents showed a significant increase from 1989 (two documents published by Kenya and US) to 2019 (135 documents, published mostly by US with 30 documents) ($p < 0.001$). This growth continued to be significant during the timeframe, although there were some modifications in the p-value and the grade of the significance (from 2000 to 2019 = $p < 0.01$; and from 2010 to 2019 = $p < 0.05$). Additionally, the trend of publications was analyzed according to the number of citations per year of publication, showing significant differences between documents published before 2017 (mean of documents with citations = 14.35; SD = 24.71) and after 2017 (mean of documents with citations = 0.15.15; SD = 7.02) ($p < 0.001$). The main language of these documents published was English (92.4%), followed by Spanish (1.3%), German (1.0%), French (1.0%) and Italian (0.8%).

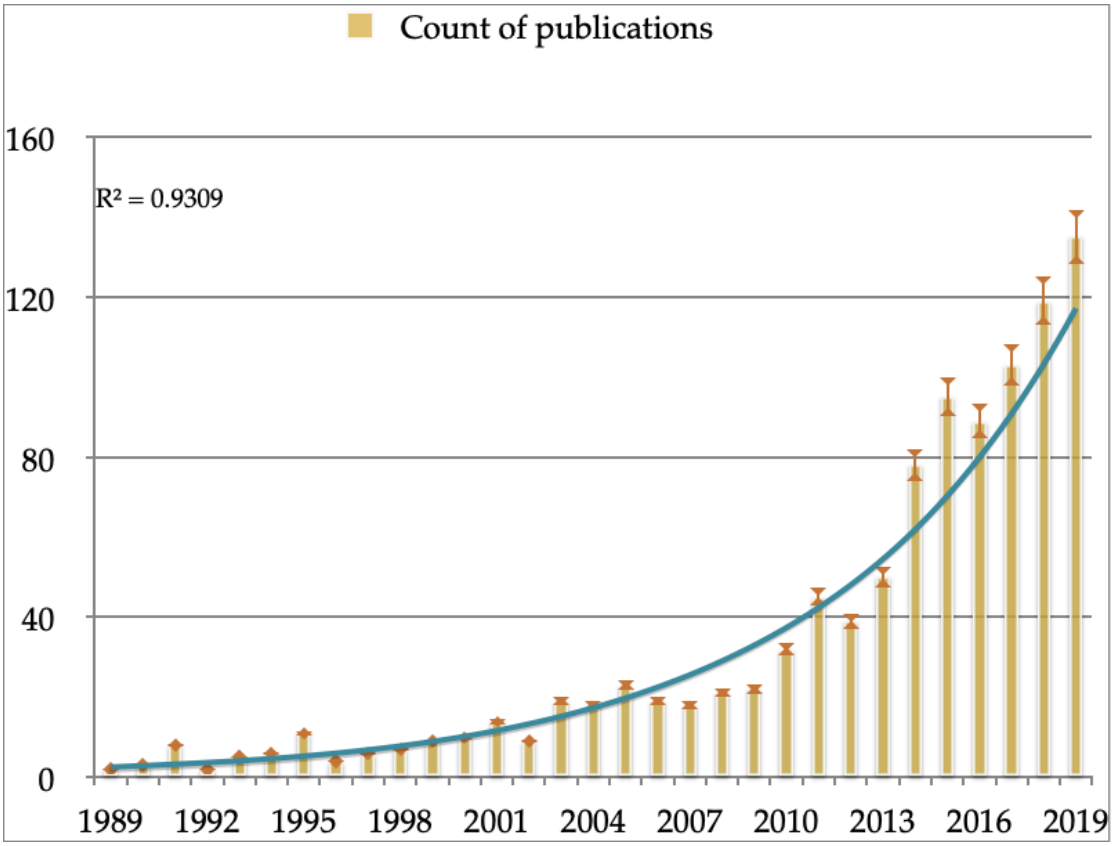


Figure 2. Number of papers per year and exponential trendlines. Note: the error bars and exponential trendline are based on percentage and count of publications.

II.3.2. International Dissemination of Publications and Collaorations Between Countries

Table 2 indicated that most documents were published by the US (with 369 documents), followed by the UK (55 documents), Australia (51 documents), Canada (50 documents), and Germany (55 documents). The mean of publications of the top five countries showed difference between US (mean = 11.9), UK (mean= 1.8), Australia (mean= 1.7), Canada (mean = 1.6) and Germany (mean = 1.2). Furthermore, the Chi-square test for a sample indicated significant differences between countries for the production of documents ($p < 0.001$), with a significant difference between US and other countries. Additionally, Cramer's V test was used to determine the size of the effect for country and publications according to the years, showing significant differences between countries ($p < 0.001$). However, the value of the test (Cramer's V= 0.32) was lower than expected, proving less association between the variables of country and production of documents per year.

Table 2. Number of papers and citations per country from the data.

Ranking	Country	Count of Documents	Frequency	Number of Documents with Citations	Frequency
1	United States	369	36.1%	341	37.2

2	United Kingdom	55	5.4%	53	5.8
3	Australia	51	5.0%	50	5.5
4	Canada	50	4.9%	48	5.2
5	Germany	37	3.6%	34	3.7
6	Italy	33	3.2%	32	3.5
7	China	32	3.1%	29	3.2
8	Netherlands	31	3.0%	29	3.2
9	India	28	2.7%	23	2.5
10	France	27	2.6%	21	2.3
11	Brazil	22	2.2%	19	2.1
12	South Africa	22	2.2%	18	1.9
13	Japan	21	2.1%	18	1.9
14	Spain	19	2.0%	15	1.6
15	Russia	14	1.4%	11	1.2
16	Sweden	12	1.2%	10	1.1
17	Switzerland	12	1.2%	9	1.0
18	South Korea	11	1.1%	9	1.0
19	Finland	10	1.0%	8	0.9
20	Belgium	9	0.9%	8	0.9
21	Mexico	8	0.8%	8	0.9
22	Norway	8	0.8%	7	0.8
23	Poland	8	0.8%	7	0.8
24	Portugal	7	0.7%	6	0.7
25	Others	96	9.4%	99	10.8

Table 3 showed how among the top ten publications with more citations, most documents were: published in the US, articles, focused on public health, and published in the first decade of the 21 st century. Furthermore, the table showed how most journals were from a medical area, with all of them ranking in the first quartile (Q1) according to journal impact (Journal Citation Report), which were related to the citations ($p < 0.01$).

Table 3. The top ten most cited documents.

Ranking	Title	Year	Journal	Thematic Area	Study	Country	Citations
1	Environmental contamination makes an essential contribution to hospital infection	2007	Journal of Hospital Infection	Public, environmental health	Article	United States	414
2	A smartphone dongle for diagnosis of infectious diseases at the point of care	2015	Science Translational Medicine	Medicine research and experimental	Article	United States; Rwanda	219
3	Behavior change versus culture change: Divergent approaches to managing workplace safety	2005	Safety Science	Engineering, industrial	Article	United States	173
4	Percutaneous Injury, Blood Exposure, and Adherence to Standard Precautions: Are Hospital-Based Health Care Providers Still at Risk?	2003	Clinical Infectious Diseases	Infectious Diseases	Article	United States	118
5	Surveying wearable human assistive technology for life and safety critical applications: Standards, challenges and opportunities	2014	Sensors	Engineering, electrical & electronic	Review	Qatar	113

6	Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals	2016	Antimicrobial Resistance and Infection Control	Public, environmental health	Review	United States	104
7	Epidemiology of hospital sharps injuries: A 14-year prospective study in the pre-AIDS and AIDS eras	1991	American Journal of Medicine	Medicine general and internal	Article	United States	100
8	Needlestick injuries in the United States. Epidemiologic, economic, and quality of life issues	2005	AAOHN journal	Public, environmental health	Review	United States	97
9	The relationship between return on investment and quality of study methodology in workplace health promotion programs	2014	American Journal of Health Promotion	Public, environmental health	Article	Australia	85
10	Uniform: an evidence review of the microbiological significance of uniforms and uniform policy in the prevention and control of healthcare-associated infections. Report to the Department of Health (England)	2007	Journal of Hospital Infection	Public, environmental health	Review	United Kingdom	78

The number of citations (mean = 12.4; SD = 21.4) per document was analyzed showing a difference between countries ($p < 0.001$) and year of publication ($p < 0.001$). The top five countries with more documents (Table 2) had significant differences ($p < 0.01$) regarding the number of citations and documents with citations, with the US the leader (mean = 14.9; SD = 30.4; CI 95% = 18.1–11.7), followed by UK (mean = 11.7; SD = 13.4; CI 95% = 15.4–7.9), Australia (mean = 9.7; SD = 13.3; CI 95% = 13.5–5.8), Canada (mean = 8.6; SD = 9.6; CI 95% = 11.4–5.8) and Germany (mean = 8.9; SD = 11.8; CI 95% = 13.1–4.8). In this sense, the number of citations of the main countries were 341 citations for US (37.2%), 53 citations UK (5.8%); 50 citations Australia (5.5%), 48 citations for Canada (5.2%), and 37 for Germany (3.7%). The correlation between number of publications per country and number of citations was significant (Spearman's test = 0.98; $p < 0.01$), although in other countries (Table 2), such as Spain, with a lower number of publications and citations, the correlation was lower (Spearman's test = 0.86; $p < 0.05$). Additionally, significant differences between citations of articles published by the US and documents published by other countries were found ($p < 0.001$). The correlation test proved how documents published in the US had a positive association with more citations (Spearman's test = 0.198; $p < 0.001$), although the coefficient was lower than expected.

Furthermore, a concurrency analysis was carried out to determine possible associations between countries, showing different clusters (Figure 3). Figure 3 shows countries' collaboration networks between 45 countries, representing the frequency of documents by the size of the circle. The figure represents the nine clusters, with the first, red cluster led by US. The red cluster, with nine countries and 279 links to countries, represents 51.3% of the collaborations between the countries. This cluster is formed by the US (presented in 408 documents), Colombia (five documents), Mexico (11 documents), India (37 documents), and South Africa (presented in 33 documents). The second cluster, in green, represents 18.1% of the collaborations between countries, led by the UK (being in 96 documents and with 36 links to other countries). This cluster was the second in number of countries (eight countries) and links, formed by the UK, Brazil (26 documents), Japan (23 documents), Russia (15 documents), Portugal (eight documents), Austria (six documents), Denmark (six documents) and Hungary (five documents). The third cluster (in blue) reflects 8.1% of the collaborations between the countries, being formed by seven countries. This cluster was led by Spain (presented in 26 documents and with 16 links to different countries), followed by Belgium (15 documents and 15 links), Finland (14 documents and 19 links), Poland (nine documents and four links), Turkey (eight documents and 13 links), Ireland (six documents and six links) and Greece (five documents and four links). The fourth cluster (yellow), represents 8.1% of the collaboration and formed by five countries, which leader Canada (presented in 65 documents and with 17 links to different countries), followed by Italy, France, Norway, and Tanzania. The following cluster in purple, represents 5.2% of the collaborations,

formed by four countries with Germany as the leading country (presented in 50 documents and with 17 links to different countries), followed by Iran, Netherlands, and Nigeria. The next cluster (light blue) was formed by four countries (China, Singapore, South Korea and Singapore) was led by China (presented in 35 documents and with 15 links). The seventh (orange) and eighth (brown) clusters were formed by three countries each. The final cluster (pink) was formed by two countries, Sweden (presented in 25 documents and with 24 links to other countries) and Saudi Arabia.

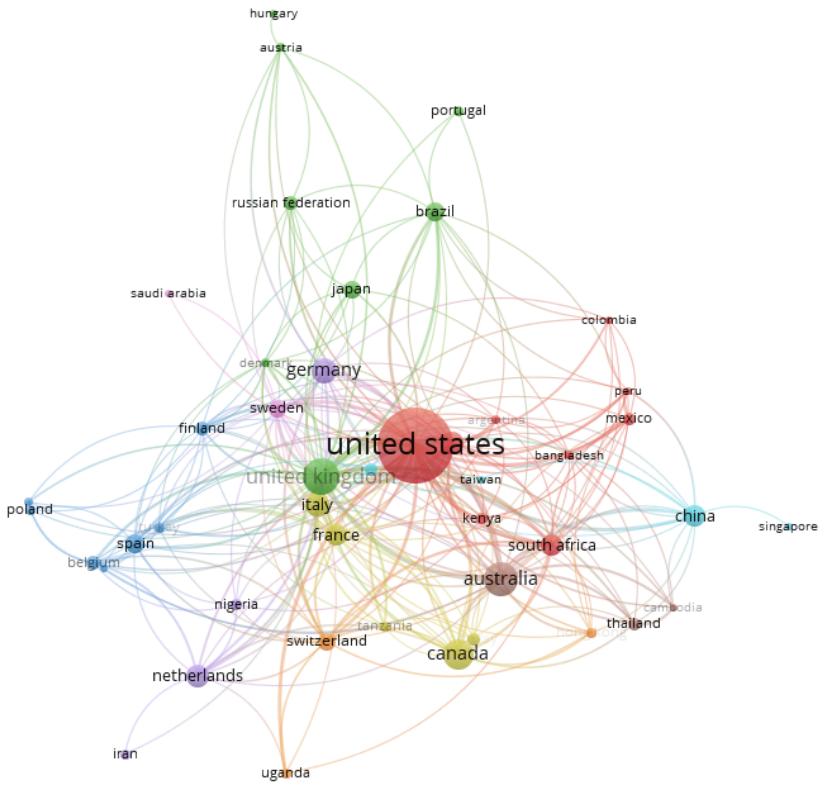


Figure 3. Collaboration among countries.

II.3.3. Institution and Jounarls More Relevant in the Topic

In Table 4, the ten organizations with the highest rates of publication in the occupational safety regarding ICTs in the healthcare sector were analyzed. The University of Toronto is in the first position, with 40 publication, followed by the CDC with 31 documents. Next is the National Institute for Occupational Safety and Health, in third position (22 documents), the University of Calgary (18 documents) and followed by the University of Washington, Seattle (17 documents). These top ten institutions represented the 18.8% the publications and the 20.3% of the citation in the topic studied. Additionally, seven out of the ten institutions with higher number of publications were from US, followed by Canada, which was the fourth country with higher number of publications.

Table 4. Publications and citations by the top ten international institutions.

Affiliation	Country	Publications	Frequency	Number of Documents with Citations	Frequency
University of Toronto	Canada	40	3.9%	39	4.2%
Centers for Disease Control and Prevention	United States	31	3.0%	29	3.2%
National Institute for Occupational Safety and Health	United States	22	2.2%	22	2.4%
University of Calgary	Canada	18	1.8%	18	2.0%
University of Washington, Seattle	United States	17	1.7%	16	1.7%
University of Cape Town	South Africa	14	1.4%	14	1.5%
Johns Hopkins Bloomberg School of Public Health	United States	13	1.3%	12	1.3%
Duke University	United States	13	1.3%	13	1.4%
University of Melbourne	Australia	12	1.2%	11	1.2%
Brigham and Women's Hospital	United States	12	1.2%	12	1.3%

Additionally, the prominent ten journals with higher numbers of publications in this topic, according to the Scopus database, have been analyzed (Table 5). Most of the journals with the greatest number of documents published and the highest impact factors are from the US and UK, followed by Canada. Among the top ten journals, *Journal of Hospital Infection*, which is placed in fifth place, had 612 citations, representing 5.8% of the total (total citations = 10,561), followed by *Safety Science* (with 543 citations and representing 5.1%). The second journal, *American Journal of Infection Control,* had 200 citations; and the third journal had 33 citations. The ten top journals summed up 2114 citations, representing 20.0% of the citations form all the journals in the topic.

Table 5. Quartile and Journal Citation Report (JCR) of ten principal journals.

Source	Documents Published	Quartile Score	JCR (2019)	Documents (2019)	Citable Items (2019)	Frequency of Articles	Country
Safety Science	22	Q1	4.11	461	512	90.82%	Netherlands
American Journal of Infection Control	19	Q2	2.29	345	303	88.45%	United States
BMC Public Health	13	Q1	2.51	1764	1741	94.77%	United Kingdom
International Journal of Environmental Research and Public Health	12	Q1	2.47	5186	2843	90.82%	United States
Journal of Hospital Infection	12	Q1	3.27	272	202	87.13%	United Kingdom
BMJ Open	11	Q2	2.50	4303	3887	85.13%	United Kingdom
Infection Control and Hospital Epidemiology	11	Q2	2.94	367	236	88.56%	United States
Journal of Medical Internet Research	11	Q1	5.03	1895	643	84.45%	Canada
Malaria Journal	10	Q1	2.63	450	431	93.50%	United Kingdom
Plos One	10	Q2	2.74	2.92	11,244	97.31%	United States

The analysis of the co-citations of journals also showed that these main journals (i.e., *Safety Science* or *Infection Control and Hospital Epidemiology*) were linked to other important journals (i.e., *The Lancet*) and had a major part in the clusters formed, with three (*Safety Science*, *Infection Control and Hospital Epidemiology* and *BMC Public Health*) of the seven leading journals of the cluster among the top ten (Table 5). The mapping (Figure 4) created indicated seven clusters, formed of 160 journals and 4758 links between the different journals. The first cluster (red) was formed by 51 journals, led by *Journal of Occupational and Environmental Medicine* (J. Occup. Environ. Med.), with 196 citations (Q3 and JCR of 1.64). The second cluster (green) was formed by 35 journals, led by *BMC Public Health* with 186 citations (Table 5). The third cluster (blue) was formed by 26 journals, led by *The Lancet* (Lancet)

with 508 citations (Q1 and JCR of 60.39), connected to *Plos One,* which had 253 citations from other journals (Table 5). The fourth cluster (yellow) was formed by 23 journals, led by *Infection Control and Hospital Epidemiology* (Infect. Control. Hosp. Epidemiol.) with 404 citations (Table 5). The fifth cluster (purple) was formed by 179 journals, led by *Safety Science* (Saf. Sci.) with 275 citations (Table 5). The sixth cluster (pink) was formed by four journals, led by *New England Journal of Medicine* (N. Engl. J. Med.) with 225 citations (Q1 and JCR of 74.69). The final cluster (orange) was formed by two journals, led by *American Journal of Epidemiology* (N. Engl. J. Med.) with 52 citations (Q1 and JCR of 4.53).

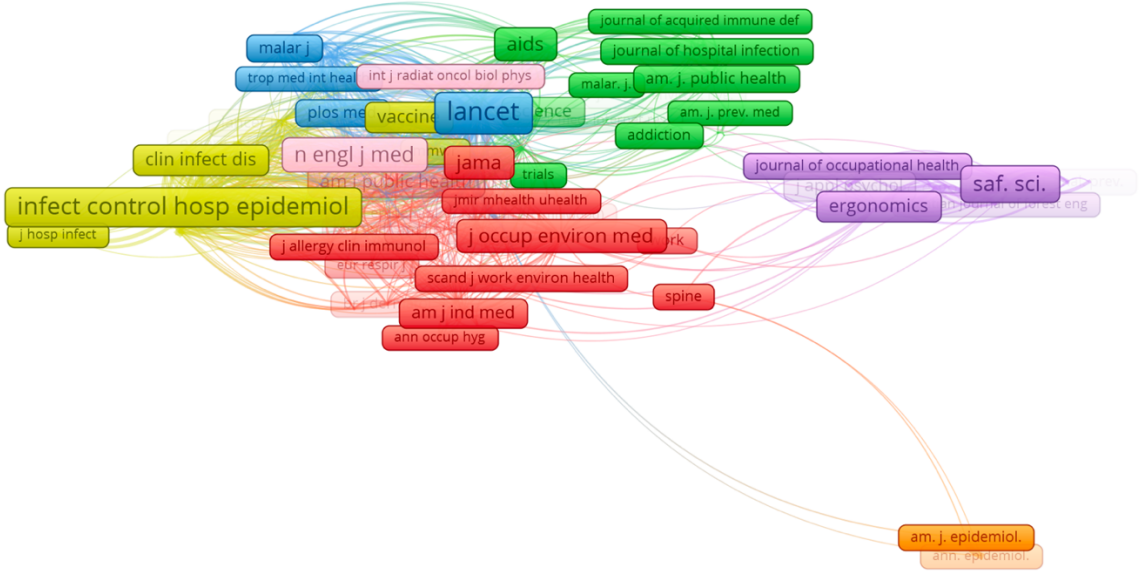


Figure 4. Co-citation between journals..

The frequency of articles among the documents published by the top ten journals (Table 5) was between 80–90%, which matched the most frequent type of document from the data. In this sense, the most common documents published were articles (72.2%), reviews (14.9%), conference papers (8.1%) and book chapters (1.4%). The year of publication was negatively linked to the type of document, reducing the number of articles, which were the main type of documents, and increasing the number of reviews ($p = 0.002$). Furthermore, the citations per year showed significant differences between citations of articles published before 2007 ($p < 0.001$). The correlation test proved how documents published more recently had a negative association with citations (Spearman's test = −0.385; $p < 0.001$).

II.3.4. Determination of Connections between Authors Inside the Scientific Field

A further analysis was carried out based on the dominant authors in the topic, to determine co-citation among authors (Table 6 and Figure 5). Table 6 shows the scientific productions of the top five

researchers focused on this subject during the last decade. Yan, L.L., from Canada, was the top author (6 documents), with an *h-index* of 48, 256 published documents and 9166 citations. Yan, L.L., started to publish in 2002 with a conference paper.

Table 6. Progress of the top five authors' works during the last decade.

Year	Yan, L.L.	Brouqui, *p.*	Iavicoli, S.	Mayer, K.H.	Canavati, S.E.	Total Documents
2009	0	0	0	0	0	0
2010	0	0	1	0	0	1
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	1	1	0	0	0	2
2015	1	1	1	0	0	3
2016	0	1	0	1	3	5
2017	1	1	0	1	0	3
2018	0	0	0	0	0	0
2019	3	0	1	1	0	5
Total Documents	6	4	3	3	3	19

According to the *h-index* of the top five authors, Mayer, K.H. had more documents and citations, with an *h-index* of 93, 1187 documents and 45,840 citations. The second author, Brouqui, *p.* had 464 documents, 14,176 documents and an *h-index* of 60. The following author was Iavicoli, S. with 245 documents, 2354 citations and an *h-index* of 27. The last author was Canavati, S.E. with 18 documents, 240 citations and an *h-index* of 9, whose first document was published in 2011. The author with the highest *h-index* and documents was from the US, followed by France. The co-citations among authors was analyzed to determine mapping based on the references (Figure 5). The mapping identified seven clusters, with 86 items and 971 links. The first cluster (red) was formed by 21 authors, led by Teizer J., with one document and 62 citations (*h-index* of 40, 156 documents published and 5443 citations). The second cluster (green) was formed by 19 authors, led by Goetzel R. Z. with no documents and 45 citations (*h-index* of 40, 182 documents published and 6927 citations). The third cluster (blue) was formed by 15 authors, led by Zohar D. with one document and 46 citations (*h-index* of 32, 51 documents published and 7048 citations). The fourth cluster (yellow) was formed by 13 authors, led by Pittet D. with one document and 113 citations (*h-index* of 91, 589 documents published and 35,692 citations). The fifth cluster (purple) was formed by eight authors, led by Cuijpers *p*. with two documents and 55 citations (*h-index* of 108, 788 documents published and 41,935 citations). The sixth cluster (pink), was formed by seven authors, led by Altman D.G. with no documents and 40 citations (*h-index* of 218, 1064 documents published and 352,962 citations). The final cluster (orange) was

formed by three authors, led by Weber D.J. with one document and 28 citations (*h-index* of 64, 443 documents published and 15,845 citations).

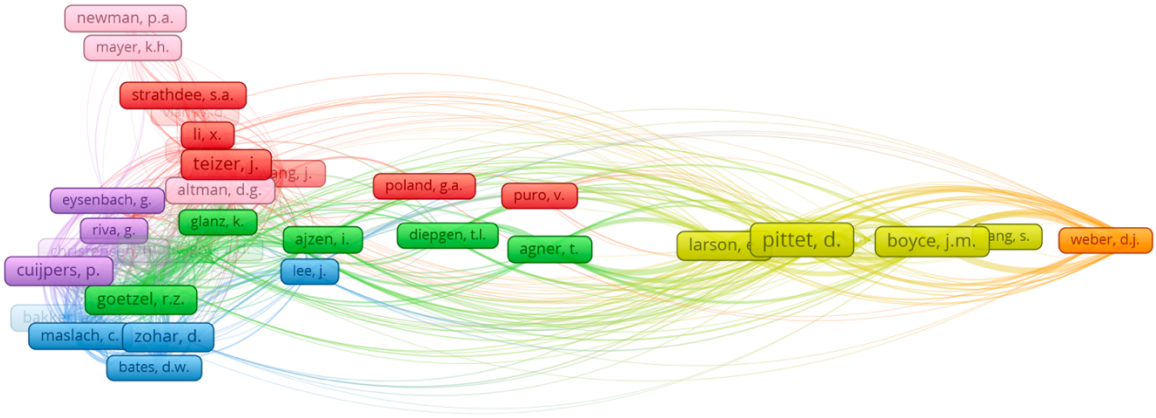


Figure 5. Co-citation between authors.

II.3.5. Determination of Sub-Topics Utilizing the Keywords

The most common topics in the data were identified using the index keywords of each document (Figure 6). The topics identified eight clusters (formed by 993 keywords with 84,876 links between them). The first and main cluster (formed by 190 keywords) focused on occupational health, prevention of diseases and accidents, and inclusion of ICTs (21.2% of the documents), such as bioengineering (red cluster). This first cluster (red) represented the main sub-topic inside the topic of occupational safety and health linked to ICTs in the healthcare sector. The second sub-topic (green), formed by 172 keywords, represented 18.3% of the sub-topics, focused on viruses and emergency pathologies that affect the global population and therefore were risks. The third cluster (in blue) was formed by 169 keywords and its frequency in the data was 16.8%. This sub-topic was based on workers' behavior, such as smoking, and mental health, such as stress, burnout syndrome, and physiological support. The fourth cluster, in yellow, represented 16.4% of the sub-topics and was formed by 148 keywords. This cluster has as its main theme the prevention and control of infections and diseases, and correct procedures, such as handwashing and training. The fifth cluster (in purple), formed by 124 keywords and whose frequency in the data was 9.3%, concentrated on the aging of the working population and healthy factors. The six cluster (in pink, formed by 79 keywords and representing 8.2% of the sub-topics) was based on needlestick, hepatitis, devices, and prevention. The seventh cluster (in orange) was formed by 33 keywords and presented 5.1% of the nine sub-topics (clusters), and was centered on cancer, initial detention, and ultraviolet rays. The eighth cluster (in brown), was formed by 18 keywords and had a frequency among the clusters of 4.7%, and was based on insurance, preventive health services, and programs.

Figure 6. Co-occurrence of most common index terms per document. Note: the colors of the nodes indicate principal components of the data structure; the node size was scaled to the index keywords' occurrences.

II.4. Discussion

This paper studied the global trend of 1021 research publications regarding ICTs in occupational safety and health of healthcare workers. The results have shown that the publication rate in this topic has increasingly grown from 1989 to 2019, and most publications were from the US and other developed countries. Although the trend of publications increased with the growth of ICTs in the healthcare sector, this trend seemed to highly increase from the beginning of the 2000s, correlating with the popularity and increased development of ICTs in the working environment. The data showed a significant difference between ICTs in OSH in 1989 compared to 2019, which could be related to the revolution of technology [48,49]. Based on previous work and the current trend linked with the fourth technological revolution, the impact of ICTs in the OSH of the healthcare sector, such as nanotechnology, sensors or virtual reality [50–52], might likely have a major impact over the next ten years [53].

The analysis of the data showed that most articles were published in the US and other English nations, with the main language being English, which could be related to affiliation since the main

research centers focused on OSH, such as the Center for Control Disease and Prevention (CDC), are situated in US, UK or Canada [35]. Additionally, the main institutions, journals, journals and co-citations between authors and journals that published in this topic were also from these same countries (US or UK). These results could also reflect the historical background of each country regarding OSH, the integration of ICTs, the relevance of scientific production in this topic, health prevention measures, the number of inhabitants, and even the financial budget for OSH [22,54–57]. Moreover, it is interesting to note that the network of countries of this study showed how the countries with a higher frequency of publications were the leaders of each cluster. Though it is somewhat surprising that no main country was linked with other more relevant countries, they were linked to minor countries following a more aleatory structure. Nevertheless, these connections could be based on political, historical, and economic links [58–61].

Moreover, these countries where the main journals or authors carried out the research, showed associations between authors from different institutions and areas of knowledge. This interesting finding highlighted the existence of associations in the scientific community. Inside the community created, the central nucleus showed the significance of the main authors with more citations in the area, being connected to the citations, *h-index* and documents published. These results seemed to match previous papers that indicated that a connection between authors was linked to the relevance and citations of the author [62,63]

The current study also found that the most common types of publication were articles, followed by reviews. Although the type of document changed with the passing of the years, these results were contradictory to previous studies that highlighted how in medicine or public health, reviews were usually more common [64–66]. Although they were increasing, this reduced number of reviews could be linked to the need for previous publications and the creation of scientific knowledge in any thematic area [67–69].

This study's results indicate that the topics of the studies, based on the index keywords and resulting in multiple sub-areas, were related to OSH in the healthcare sector, and some measured ICTs. The sub-topics highlighted the principal concerns and issues present at the beginning of the 21st century and that continue today, such as prevention, biological exposure, and training [66,70–72]. Another main topic was related to mental health, for prevention and early detection. This topic seems to reflect one of OSH's main issues for healthcare workers that has increased after the pandemic with Covid−19 increasing sleeping issues and burnout syndrome [29,73,74]. The relevance of the different topics and supremacy of prevention might be related to its evolution and significance [75–77]. Nevertheless, it seems that inclusion of ICTs is more delimited to prevention and promotion of health among workers, screening systems, such as cancer [78], and new devices to prevent infections, which could be a representation of the reduced inclusion of ICTs in OSH in the healthcare sector when

compared with other sectors [49,79–81]. Additionally, the topics seem to focus on the positive effect of ICTs in the OSH for the healthcare sector, although the European Agency indicated that the ICTs might also have negative effects for healthcare workers [79].

Another intriguing result was the citations per document and year of publication of the documents, with 2007 the breaking point. The citations per document also seemed to be related to the journal's relevance and the thematic area. These results corroborate the findings of a great deal of previous work that indicated that the relevance of a lot of research seems to be based on the journal citation report and index [82–84].

These findings may be somewhat limited by the choice of keywords used for the research, by which the screening and selection of the data could have limited the number of documents and, therefore, the results and the journals. Additionally, it is important to bear in mind the possible bias in these results, based on the selection of a unique database, instead of combining two or more databases. This research focused on including close terms related to technology, OSH and healthcare workers, and excluding other terms for technology, such as "robotics" or "virtual reality", which could have limited the results. This was primarily to avoid the possible inclusion of publications not focused on the healthcare sector in which these technologies are less present [85]. Moreover, the study of index keywords and, therefore, the topics might not represent the totality of the research carried out in the healthcare sector, as not all the keywords used were MeSH terms. Finally, the Boolean operators used, which were "OR" and "AND", may have incorporated documents in which the main objective may differ from the objective of this paper. However, based on the sample size and the screening process, the possible error could be considered insignificant and could provoke little change in the result obtained in this research.

Overall, these findings have significant implications for the understanding of how the role of ICTs will evolve or continue in OSH for the healthcare sector, with this role focused on prevention via education, prevention, and early screening. Additionally, this scientometric analysis adds further information to the literature by elucidating the growing importance of ICTs in OSH and the future of occupational health in a sector that continues to have concerns regarding mental health or biological exposure [86,87]. These results may help to inform future investments in occupational public health, integrating new technologies and surveillance devices among workers to prevent health issues, who are traditionally a group at risk and that continues to have difficulties in modified behaviors [88,89]. The bibliometric visualizations also provide an accessible means of communicating the key findings to researchers, policymakers, and those working in public health.

II.5. Conclusions

This paper has argued that ICTs are included in the OSH for the healthcare sector, mainly in prevention and screening, although it seems that the most significant development of ICTs for this field is yet to come. In conclusion, this paper presented the global research patterns and current interests and identified the areas in which the ICTs are still missing or are less included. This research presents the main interest in the OSH related to the healthcare sector. Additionally, the results have highlighted the need for more studies focused on ICTs' negative effect on healthcare workers. Nevertheless, more work will need to be done to determine the grade of inclusion or usage of ICTs for occupational health and safety among healthcare workers and organizations, as well as specific protocols or technological tools developed as technical safety measures.

Author Contributions: Conceptualization, A.C-A. and M.V-A.; methodology, E.V-A. and P.A-M.; validation E.V-A. and P.R-M.; formal analysis, E.V-A., P.R-M., and P.A-M.; investigation, E.V-A., M.V-A., P.A-M. and M.D.R.M.; resources, E.V-A. and P.R.-M.; data curation P.A-M. and E.V-A.; writing—original draft preparation, M.V-A., P.A-M., and E.V-A.; writing—review and editing, M.V-A. and A.C-A.; supervision, M.D.R.M., and P.A-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the "IDEP/Escuela de Doctorado" of the University of Cordoba.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Mendonça, S. The revolution within: Ict and the shifting knowledge base of the world's largest companies. *Econ. Innov. New Technol.* **2006**, *15*, 777–799.
2. Aiello, A.E. Invited commentary: Evolution of social networks, health, and the role of epidemiology. *Am. J. Epidemiol.* **2017**, *185*, 1089–1092.
3. Firth, J.; Torous, J.; Stubbs, B.; Firth, J.A.; Steiner, G.Z.; Smith, L.; Alvarez-Jimenez, M.; Gleeson, J.; Vancampfort, D.; Armitage, C.J.; et al. The "online brain": How the internet may be changing our cognition. *World Psychiatry* **2019**, *18*, 119–129.
4. Colosio, C.; Mandic-Rajcevic, S.; Godderis, L.; van der Laan, G.; Hulshof, C.; van Dijk, F. Workers' health surveillance: Implementation of the directive 89/391/EEC in Europe. *Occup. Med.* **2017**, *67*, 574–578.
5. Anwar, M.M.; Liu, C.; Li, J. Discovering and tracking query oriented active online social groups in dynamic information network. *World Wide Web* **2019**, *22*, 1819–1854.
6. Rafiei, M.; Ezzatian, R.; Farshad, A.; Sokooti, M.; Tabibi, R.; Colosio, C. Occupational health services integrated in primary health care in Iran. *Ann. Glob. Health* **2015**, *81*, 561.
7. Button, D.; Harrington, A.; Belan, I. E-learning & information communication technology (ICT) in nursing education: A review of the literature. *Nurse Educ. Today* **2014**, *34*, 1311–1323.
8. Welch, L.S.; Russell, D.; Weinstock, D.; Betit, E. Best practices for health and safety technology transfer in construction. *Am. J. Ind. Med.* **2015**, *58*, 849–857.

9. de Lima, I.C.V.; Galvão, M.T.G.; de Alexandre, H.O.; Lima, F.E.T.; de Araújo, T.L. Information and communication technologies for adherence to antiretroviral treatment in adults with HIV/AIDS. *Int. J. Med. Inform.* **2016**, *92*, 54–61.
10. Dev, H.; Ali, M.E.; Hashem, T. User Interaction Based Community Detection in Online Social Networks. In Proceedings of the Database Systems for Advanced Applications; Bhowmick, S.S., Dyreson, C.E., Jensen, C.S., Lee, M.L., Muliantara, A., Thalheim, B., Eds.; Springer International Publishing: Cham, 2014; pp. 296–310.
11. Tomás, R.; Cano, M.; Santamarta, J.C.; Hernández-Gutiérrez, L.E. New approaches for teaching soil and rock mechanics using information and communication technologies. *Procedia Soc. Behav. Sci.* **2015**, *191*, 1644–1649.
12. Vaterlaus, J.M.; Patten, E.V.; Roche, C.; Young, J.A. #Gettinghealthy: The perceived influence of social media on young adult health behaviors. *Comput. Hum. Behav.* **2015**, *45*, 151–157.
13. Hislop, D.; Axtell, C. Mobile phones during work and non-work time: A case study of mobile, non-managerial workers. *Inf. Organ.* **2011**, *21*, 41–56.
14. Tremblay, D.-G.; Thomsin, L. Telework and mobile working: Analysis of its benefits and drawbacks. *Int. J. Work Innov.* **2012**, *1*, 100–113.
15. Balasubramaniam, S.M.; Bhargava, S.; Agrawal, N.; Asif, R.; Chawngthu, L.; Sinha, P.; Kumar, S.; Sood, B. Blending virtual with conventional learning to improve student midwifery skills in India. *Nurse Educ. Pract.* **2018**, *28*, 163–167.
16. Gagliardi, D.; Marinaccio, A.; Valenti, A.; Iavicoli, S. Occupational safety and health in Europe: Lessons from the past, challenges and opportunities for the future. *Ind. Health* **2012**, *50*, 7–11.
17. Alrazi, B.; de Villiers, C.; van Staden, C.J. A comprehensive literature review on, and the construction of a framework for, environmental legitimacy, accountability and proactivity. *J. Clean Prod.* **2015**, *102*, 44–57.
18. Berkowsky, R.W. When you just cannot get away. *Inf. Commun. Soc.* **2013**, *16*, 519–541.
19. González-Menéndez, E.; López-González, M.J.; Menéndez, S.G.; González, G.G.; Bayona, Á. Principales consecuencias para la salud derivadas del uso continuado de nuevos dispositivos electrónicos con pvd. *Rev. Esp. Salud Pública* **2019**, *93*, e1–e11.
20. Harrison, J. Occupational safety and health in the United Kingdom: Securing future workplace health and wellbeing. *Ind. Health* **2012**, *50*, 261–266.
21. Kranzberg, M. Technology and history: Kranzberg's laws. *Technol. Cult.* **1986**, *27*, 547.
22. Verra, S.E.; Benzerga, A.; Jiao, B.; Ruggeri, K. Health promotion at work: A comparison of policy and practice across Europe. *Saf. Health Work* **2019**, *10*, 21–29.
23. Papadopoulos, G.; Georgiadou, P.; Papazoglou, C.; Michaliou, K. Occupational and public health and safety in a changing work environment: An integrated approach for risk assessment and prevention. *Saf. Sci.* **2010**, *48*, 943–949.
24. Badri, A.; Boudreau-Trudel, B.; Souissi, A.S. Occupational health and safety in the industry 4.0 era: A cause for major concern? *Saf. Sci.* **2018**, *109*, 403–411.
25. Gochfeld, M. Occupational medicine practice in the United States since the industrial revolution: *J. Occup. Environ. Med.* **2005**, *47*, 115–131.

26. Batham, C.; Yasobant, S. A risk assessment study on work-related musculoskeletal disorders among dentists in Bhopal, India. *Indian J. Dent. Res.* **2016**, *27*, 236–241.
27. Dirkzwager, A.J.E.; Yzermans, C.J.; Kessels, F.J.M. Psychological, musculoskeletal, and respiratory problems and sickness absence before and after involvement in a disaster: A longitudinal study among rescue workers. *Occup. Environ. Med.* **2004**, *61*, 870.
28. Yasobant, S.; Rajkumar, P. Work-related musculoskeletal disorders among health care professionals: A cross-sectional assessment of risk factors in a tertiary hospital, India. *Indian J. Occup. Environ. Med.* **2014**, *18*, 75–81.
29. Spoorthy, M.S.; Pratapa, S.K.; Mahant, S. Mental health problems faced by healthcare workers due to the COVID-19 pandemic—A review. *Asian J. Psychiatry* **2020**, *51*, 102119.
30. Strelioff, W.; Lavoie-Tremblay, M.; Barton, M. Collaborating to embrace evidence—Informed management practices within Canada's health system. *HealthcarePapers* **2007**, *7*, 36–41.
31. Yassi, A.; Ostry, A.; Spiegel, J.; Walsh, G.; de Boer, H. A collaborative evidence-based approach to making healthcare a healthier place to work. *Hosp. Q.* **2002**, *5*, 70–78.
32. Camarillo, D.B.; Krummel, T.M.; Salisbury, J.K., Jr. Robotic technology in surgery: Past, present, and future. *Am. J. Surg.* **2004**, *188*, 2–15.
33. Haluza, D.; Jungwirth, D. ICT and the future of health care: Aspects of health promotion. *Int. J. Med. Inform.* **2015**, *84*, 48–57.
34. Spinazzè, A.; Cattaneo, A.; Cavallo, D.M. Respiratory protection considerations for healthcare workers during the COVID-19. *Ann. Work Expo Health* **2020**, *64*, 559–564.
35. Lucchini, G.R.; London, L. Global occupational health: Current challenges and the need for urgent action. *Ann. Glob. Health* **2014**, *80*, 251.
36. Westbrook, J.I.; Braithwaite, J.; Gibson, K.; Paoloni, R.; Callen, J.; Georgiou, A.; Creswick, N.; Robertson, L. Use of information and communication technologies to support effective work practice innovation in the health sector: A multi-site study. *BMC Health Serv. Res.* **2009**, *9*, 201.
37. Rowe, M. Information and communication technology in health: A review of the literature. *J. Community Health Sci.* **2008**, *3*, 68–77.
38. Schaper, L.K.; Pervan, G.P. ICT and OTs: A model of information and communication technology acceptance and utilisation by occupational therapists. *Int. J. Med. Inform.* **2007**, *76*, S212–S221.
39. Reeves, B.; Borgman, C.L. A bibliometric evaluation of core journals in communication research. *Hum. Commun. Res.* **2006**, *10*, 119–136.
40. Munn, Z.; Stern, C.; Aromataris, E.; Lockwood, C.; Jordan, Z. What kind of systematic review should I conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. *BMC Med. Res. Methodol.* **2018**, *18*, 5.
41. Andrés, A. Final considerations. In *Measuring Academic Research: How to Undertake a Bibliometric Study*; Chandos Publishing: Oxford, UK, 2009; pp. 141–147, ISBN 978-1-84334-528-2.
42. Bar-Ilan, J.; Levene, M.; Lin, A. Some measures for comparing citation databases. *J. Informetr.* **2007**, *1*, 26–34.
43. Burnham, J.F. Scopus database: A review. *Biomed. Digit. Libr.* **2006**, *3*, 1.

44. Jenkins, D. Scopus—A Large Abstract and Citation Database for Research. 2017. Available online: http://www.open.ac.uk/blogs/the_orb/?p=2062 (accessed on 18 June 2020).
45. Fundación Española para la ciencia y la tecnología. Índices de Impacto. Herramienta de consulta del factor de impacto y otras métricas. Available online: https://www.recursoscientificos.fecyt.es/factor/ (accessed on 20 August 2020).
46. Centre for Science and Technology Studies, Leiden University VOSviewer. Available online: https://www.vosviewer.com (accessed on 20 August 2020).
47. van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538.
48. Nakasone, E.; Torero, M.; Minten, B. The power of information: The ICT revolution in agricultural development. *Annu. Rev. Resour. Econ.* **2014**, *6*, 533–550.
49. Rubio-Romero, J.C.; Arquillos, A.; Suárez-Cebador, M.; Carrillo-Castrillo, J. Information and Communication Technologies (ICT) in Occupational Health and Safety (OHS) courses at engineering under/degree studies. In *Occupational Safety and Hygiene*; CRC Press: Boca Raton, FL, USA, 2014; pp. 49–52, ISBN 978-1-138-00144-2.
50. Priestly, B.G.; Harford, A.J.; Sim, M.R. Nanotechnology: A promising new technology—But how safe? *Med. J. Aust.* **2007**, *186*, 187–188.
51. Torrecilla-García, J.A.; del Pardo-Ferreira, C.M.; Martínez-Rojas, M.; Rubio-Romero, J.C. The virtual reality in olive oil industry occupational health and safety: An integrative review. In *Occupational and Environmental Safety and Health*; Arezes, P.M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G., Eds.; Springer International Publishing: Cham, Germany 2019; pp. 797–805, ISBN 978-3-030-14730-3.
52. Ngubo, S.A.; Kruger, C.P.; Hancke, G.P.; Silva, B.J. An occupational health and safety monitoring system. In Proceedings of the 2016 IEEE 14th International Conference on Industrial Informatics (INDIN), Poitiers, France, 19–21 July 2016; pp. 966–971.
53. Bradbrook, S.; Ellwood, P.; Lye, D.; Reynolds, J.; Stacey, N.; Williams, H. *Foresight on New and Emerging Occupational Safety and Health Risks Associated with Digitalisation by 2025.*; European Risk Observatory Report; European Agency for Safety and Health at Work: Luxembourg, 2018; pp. 1–159.
54. Bilir, S.; Ghavam, E.; Sancak, L. *The Comparison of Occupational Health and Safety Legislation of Different Countries from the View of Inspection*; Publisher: The XXVI th Annual Occupational Ergonomics and Safety Conference El Paso, TX, USA, 2014; p. 7.
55. González-Alcaide, G.; Valderrama-Zurián, J.C.; Aleixandre-Benavent, R. The impact factor in non-English-speaking countries. *Scientometrics* **2012**, *92*, 297–311.
56. Ernesto, R. Gantman economic, linguistic, and political factors in the scientific productivity of countries. *Scientometrics* **2012**, *93*, 967–985.
57. Campbell, D.; Archambault, E.; Ventimiglia, A.; Roberge, G.; Lefebvre, C.; Picard-Aitken, M.; Côté, G.; European Commission. Directorate-general for research and innovation. In *Country and Regional Scientific Production Profiles*; Publications Office: Luxembourg, 2013; ISBN 978-92-79-33735-2.

58. Quintas, P.; Wield, D.; Massey, D. Academic-industry links and innovation: Questioning the science park model. *Technovation* **1992**, *12*, 161–175.
59. Hemmert, M.; Bstieler, L.; Okamuro, H. Bridging the cultural divide: Trust formation in university–industry research collaborations in the US, Japan, and South Korea. *Technovation* **2014**, *34*, 605–616.
60. De Fuentes, C.; Dutrénit, G. Best channels of academia–industry interaction for long-term benefit. *Res. Policy* **2012**, *41*, 1666–1682.
61. Bodas Freitas, I.M.; Marques, R.A.; de Silva, E.M.P. University–industry collaboration and innovation in emergent and mature industries in new industrialized countries. *Res. Policy* **2013**, *42*, 443–453.
62. White, H.D. Relevance theory and citations. *J. Pragmat.* **2011**, *43*, 3345–3361.
63. Schloegl, C.; Stock, W.G. Impact and relevance of LIS journals: A scientometric analysis of international and German-language LIS journals—Citation analysis versus reader survey. *J. Am. Soc. Inf. Sci. Technol.* **2004**, *55*, 1155–1168.
64. Gopalakrishnan, S.; Ganeshkumar, P. Systematic reviews and meta-analysis: Understanding the best evidence in primary healthcare. *J. Fam. Med. Prim. Care* **2013**, *2*, 9–14.
65. Wang, H.; Zhai, F. Programme and policy options for preventing obesity in China: Options for preventing obesity in China. *Obes. Rev.* **2013**, *14*, 134–140.
66. Abu-elezz, I.; Hassan, A.; Nazeemudeen, A.; Househ, M.; Abd-alrazaq, A. The benefits and threats of blockchain technology in healthcare: A scoping review. *Int. J. Med. Inform.* **2020**, *142*, 104246.
67. Cooper, C.; Booth, A.; Britten, N.; Garside, R. A comparison of results of empirical studies of supplementary search techniques and recommendations in review methodology handbooks: A methodological review. *Syst. Rev.* **2017**, *6*, 234.
68. Hacke, C.; Nunan, D. Discrepancies in meta-analyses answering the same clinical question were hard to explain: A meta-epidemiological study. *J. Clin. Epidemiol.* **2020**, *119*, 47–56.
69. Sathish, M.; Eswar, R. Systematic reviews and meta-analysis in spine surgery—How good are they in methodological quality? A systematic review. *Glob. Spine J.* **2020**, doi:10.1177/2192568220906810.
70. Fiabane, E.; Giorgi, I.; Sguazzin, C.; Argentero, P. Work engagement and occupational stress in nurses and other healthcare workers: The role of organisational and personal factors. *J. Clin. Nurs.* **2013**, *22*, 2614–2624.
71. Bahn, S.; Barratt-Pugh, L. Emerging issues of health and safety training delivery in Australia: Quality and transferability. *Procedia Soc. Behav. Sci.* **2012**, *62*, 213–222.
72. de Carvalho, D.C.; da Rocha, J.C.; de Gimenes, M.C.A.; Santos, E.C.; Valim, M.D. Work incidents with biological material in the nursing team of a hospital in Mid-Western Brazil. *Esc. Anna Nery* **2017**, *22*, doi:10.1590/2177-9465-ean-2017-0140.
73. Pascoe, M.; Alberts, J.; Wang, L.; Bruton, M.; Rogen, B.; Rehm, S.J.; McHugh, L.; Katzan, I.; Foldvary-Schaefer, N. Feasibility of electronic sleep disorder screening in healthcare workers of a large healthcare system. *Sleep Med.* **2020**, *73*, 181–186.
74. Sheraton, M.; Deo, N.; Dutt, T.; Surani, S.; Hall-Flavin, D.; Kashyap, R. Psychological effects of the COVID 19 pandemic on healthcare workers globally: A systematic review. *Psychiatry Res.* **2020**, *292*, 113360.
75. Pikkarainen, M.; Pekkarinen, S.; Koivumäki, T.; Huhtala, T. Data as a driver for shaping the practices of a preventive healthcare service delivery network. *J. Innov. Manag.* **2018**, *6*, 55–79.

76. Flores, M.; Glusman, G.; Brogaard, K.; Price, N.D.; Hood, L. P4 medicine: How systems medicine will transform the healthcare sector and society. *Pers. Med.* **2013**, *10*, 565–576.
77. Woolf, S.; Atkins, D. The evolving role of prevention in health care. *Am. J. Prev. Med.* **2001**, *20*, 13–20.
78. Friesen, M.C.; Hoar Zahm, S.; Ward, M.H.; Silverman, D.T. Chapter 42—Occupational cancer. In *Women and Health*, 2nd ed.; Goldman, M.B., Troisi, R., Rexrode, K.M., Eds.; Academic Press: Cambridge, MA, USA, 2013; pp. 629–645, ISBN 978-0-12-384978-6.
79. European Commission (Ed.). *Occupational Health and Safety Risks in the Healthcare Sector: Guide to Prevention and Good Practice*; Social Europe; Publishing Office of the European Union: Luxembourg, 2011; ISBN 978-92-79-19454-2.
80. Loosemore, M.; Andonakis, N. Barriers to implementing OHS reforms—The experiences of small subcontractors in the Australian construction industry. *Int. J. Proj. Manag.* **2007**, *25*, 579–588.
81. Quinlan, M. Organisational restructuring/downsizing, OHS regulation and worker health and wellbeing. *Int. J. Law Psychiatry* **2007**, *30*, 385–399.
82. Garfield, E. The history and meaning of the journal impact factor. *JAMA* **2006**, *295*, 90.
83. Leydesdorff, L. Mapping interdisciplinarity at the interfaces between the science citation index and the social science citation index. *Scientometrics* **2007**, *71*, 391–405.
84. Caon, M. Gaming the impact factor: Where who cites what, whom and when. *Australas. Phys. Eng. Sci. Med.* **2017**, *40*, 273–276.
85. Corvino, A.; Garzillo, E.; Arena, P.; Cioffi, A.; Monaco, M.G.L.; Lamberti, M. Augmented reality for health and safety training program among healthcare workers: An attempt at a critical review of the literature. In Proceedings of the 1st International Conference on Human Systems Engineering and Design (IHSED2018): Future Trends and Applications, Champagne-Ardenne, France, 25–27 October 2018; p. 715.
86. Belingheri, M.; Paladino, M.E.; Riva, M.A. Beyond the assistance: Additional exposure situations to COVID-19 for healthcare workers. *J. Hosp. Infect.* **2020**, *105*, 353.
87. Greenberg, N. Mental health of health-care workers in the COVID-19 era. *Nat. Rev. Nephrol.* **2020**, *16*, 425–426.
88. Rim, K.-T.; Lim, C.-H. Biologically hazardous agents at work and efforts to protect workers' health: A review of recent reports. *Saf. Health Work* **2014**, *5*, 43–52.
89. Rapisarda, V.; Loreto, C.; Vitale, E.; Matera, S.; Ragusa, R.; Coco, G.; Rapisarda, L.; Ledda, C. Incidence of sharp and needle-stick injuries and mucocutaneous blood exposure among healthcare workers. Future Microbiol. 2019, 14, 27–31

Chapter III. Tuberculosis and Other Airborne Microbes in Occupational Health and Safety

Chapter III. Tuberculosis and Other Airborne Microbes in Occupational Health and Safety

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], Pilar Ruiz-Martínez [3], Manuel Vaquero-Abellán [4,5], María Dolores Redel-Macías [2] and Pilar Aparicio-Martínez [4,5,*]

[1] SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de

[2] Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C.-A.); ig1remam@uco.es (M.D.R.-M.)

[3] GC24 Clinical and Molecular Microbiology, Instituto Maimónides, Facultad Medicina y Enfermería, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; mi1rumap@uco.es

[4] GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; en1vaabm@uco.es

[5] Departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, 14071 Córdoba, Spain

Abstract: Airborne pathogens and non-malignant infectious diseases such as tuberculosis are highly contagious and can have severe effects on healthcare workers. The symptoms of these diseases take time to manifest, which can prevent workers from noticing that they have been exposed until symptoms appear. The current paper sought to assess the occupational safety and preventative measures taken in laboratories in Spain, and to compare these measures with those reported by other studies worldwide. A cross-sectional study of workers (35–50 years old) was conducted using a web survey (N = 30), and a bibliometric analysis was carried out in the Scopus database (92 documents were selected). The occupational safety and health measures were inadequate, according to the opinions of the workers. The training ($p < 0.01$), the amount of work ($p < 0.05$), and how the workers followed their protocols ($p < 0.001$) were linked to incidents and exposure to airborne pathogens. The most significant previous publication was a report (848 citations) stating that the previous variables linked to exposure are vital for prevention. Most works focused on countries like the U.S.A. ($p = 0.009$) were reviews, with a limited number of studies focused on occupational safety.

Keywords: tuberculosis; laboratories; work environment

III.1. Introduction

Since the 18th century, when biological agents first came to be identified and defined, different countries have developed methods to prevent and control outbreaks [1]. The first efforts to control environmental factors, such as production, appeared in England during the Industrial Revolution [2]. During this period, the concept of occupational safety and health (O.S.H.) was first defined [3]. Subsequently, countries started to develop methods to control pathogens among their populations [4], such as Spain's attempts in the early 20th century to control the Spanish flu [5]. Nevertheless,

only when the World Health Organization (WHO) highlighted the need for a series of pathogen-control measures to ensure the health of the working population in 1985 were such methods included and implemented in work environments [6].

In the European Union, a Council Directive called the 89/391/EEC, also known as Framework Directive, approved an occupational safety directive for the first time in 1989, focusing on improving measures to guarantee the safety and health of workers. This directive established the fundamental principles for occupational safety described a century earlier [7,8]. However, it was not until 2004 that this directive proved that the involvement of standard legislation and the government in health and safety at work has a positive influence [8,9]. Since then, public administrations have created policies and structures to ensure the prevention of risks and promote and improve working conditions [10,11]. In this sense, maintaining workers' health has continued to be a crucial element in managing the public health of the population. However, each government has different ways of addressing the health of its workers. Governments must understand their workers and the effects of their work on their health [12,13].

One work environment that provides greater threats to its workers than other environments is health centers. Healthcare workers are exposed to many different biological pathogens, including human immunodeficiency virus, hepatitis B virus, and tuberculosis [1,14,15]. In this population, the rate of accidents and diseases related to work is around 3.2% [2]. The transmission of these agents among health professionals depends on a series of factors, the most important of which are the type of activity carried out by the worker and the effectiveness of the preventive interventions carried out [16,17]. Airborne pathogens and associated chronic respiratory diseases such as tuberculosis are highly contagious and can have severe effects on the health of workers [18]. Moreover, the symptoms of these diseases take time to manifest in the airways, which can prevent workers from realizing they have been exposed after symptoms begin [19–21]. For tuberculosis, which is caused by *Mycobacterium tuberculosis* (a Level 3 organism based on the biological risk it represents), public concern is based on the prevalence of the general population and healthcare workers that suffer from the disease [22]. In a report of WHO, it was estimated in 2015 that up to 2 billion people around the world suffer from a latent state of tuberculosis[23], which remains concerningly prevalent in low-risk countries, such as Italy [24]. In Italy in 2015, 2.1% of healthcare workers were diagnosed with latent tuberculosis infections [25]. Similar results were found in a previous systematic review which detailed that 2.9% of healthcare workers in low-incidence countries had latent tuberculosis [26].

Many factors may contribute to accidental exposure to a biological agent, although the main factors are still a lack of experience, skills, or knowledge in handling materials, and anxiety, fatigue, and a lack of care for oneself or other professionals [27]. For tuberculosis, the lack of knowledge about its transmission, the relevant preventive and biosafety measures, and the diagnosis of the disease

seems to play an important role [25]. Moreover, the current situation with the new pandemic has highlighted the lack of professional and personal protective equipment (PPE) and adequate training provided in hospitals, which could have a major impact on the prevention of airborne pathogens [28]. Moreover, the latest studies have highlighted the need to create guidelines and training programs for undergraduate students and health professionals, especially for tuberculosis and other airborne pathogens [29]. In this sense, different studies have highlighted the importance of ensuring that healthcare workers receive training and have control measures in place, although these activities are difficult to implement [25,30,31].

Laboratories and research centers where diagnostic tests are carried out carry an inherent risk for their workers, who are commonly exposed to different pathogens, including tuberculosis. Nevertheless, most studies have focused on healthcare workers or students (mainly doctors and nurses) and based on contact with patients [26]. For laboratories and research centers, most available data relate to the early nineties, reporting a prevalence of around 7.8% in the United States or 6.7 clinical laboratory technicians out of 100,000 [32]. Other studies carried out in Korea stated that the risk of contracting tuberculosis in a laboratory is 1.4 percentage higher for microscopy technicians and 7.8 for culture/defense and sciences technicians compared to non-laboratory workers [33]. Different studies have also demonstrated that laboratories are vital for the follow-up and treatment of tuberculosis [34], with updates to their protocols and improvements in access to (and training for) PPE being fundamental [35,36]. Based on these previous observations, the current paper primarily sought to determine the conditions in laboratories related to occupational safety and preventative measures, mainly in Spain. The secondary objective was to analyze the differences between the current study's results and those of other studies worldwide regarding occupational safety among healthcare professionals.

III.2. Materials and Methods

III.2.1. Survey Data Collection and Handling

A cross-sectional study using a reference population of workers aged 35 to 50 years old from different institutions (mainly Spanish centers) was conducted (Table 1). Most workers were from Europe (86.7%), being most participants from Spain (76.6%), followed by South American workers (13.3%). This study was carried out using a survey completed via the web, which included informed consent. The present study analyzed the preventative measures in microbiological laboratories, focusing mainly on airborne pathogens such as mycobacteria.

Table 1. Demographics data of the study population.

Procedure	Sample	*N*	Frequencies
Sent out survey email invitation to one worker of each center	56 email survey email invitations sent	32 for Spain (2 per the 17 regions, except for Ceuta and Melilla) in Spain (2 per region) 6 for other European centers 6 for American centers 4 for African centers 4 for Asian centers 4 for Australia/Oceanian centers	-
Average response of the surveys sent to each worker for each center	30 surveys completed	23 in Spain 4 in other European centers 3 in American centers 0 for Asian centers 0 for Australia/Oceanian centers	71.9% in Spain 67.7% in European centers 50% in American centers 0% in Asian centers 0 in Australia/Oceanian centers
	Workers of Each Center that Completed the Survey (*N* = 30)		
Variables	**Mean (SD)**	***N***	**Frequencies**
Age	42.3(7.4)	-	-
Sex	-	20 men 10 women	66.7% men 33.3% female
Ethnic background	-	23 white (European) 3 Latino 2 African descent 2 undefined	76.6% white (European) 10% Latino 6.7% African descent 6.7% undefined
Spanish and International	-	23 Spanish workers 7 international workers	76.7% Spanish 23.3% International

Note: The minimum of the sample to achieve was 30 centers (15 Spanish and 15 International) based on previous work [32]. Additionally, for the international centers the estimation was from two to three per continent. The number achieved (*N* = 30) has been of one worker per center. A note of caution is due here since the estimations were not achieved, being higher the number of Spanish centers.

This study was implemented using a questionnaire previously validated by the Mycobacteria Reference Center. This questionnaire is available in English on the University of Córdoba website (http://www.uco.es/users/jcheca/index.php?go=mva/registro.html), and was subsequently translated into Spanish and German. To work online with the translated versions, the translations were transformed into online surveys using the Google Forms application (https://docs.google.com/forms/d/1eB1lUFGV37_S1e_0oXrdH4QvwUMQbLVoZzlI_B356j4/edit). The survey was divided into seven sections: information about the study, laboratory data, work volume, and worker training. All necessary information was given to workers in order to gather personal data and information related to safety at work. This questionnaire focused on laboratory data, including the type of laboratory, the techniques carried out in those centers, and whether the centers carried out any research. The work volume was assessed based on the number of samples, the time taken to culture media, the use of tools by the workers (such as the use of microscopes, cleaning, and disinfection of the working areas), and how the workers followed the relevant protocols (cleaning, eating, clothing, etc.). The training assessment focused on the initial training and ongoing training given to workers related to occupational safety and procedures in the work environment. Assessment was also based on whether the workers were informed of occupational measures, such as providing updates to protocols for biological accidents, as well as occupational diseases. The safety at work section focused on the work environment, the availability of personal protective equipment (PPE), the frequency of cleaning and disinfection carried out by cleaners and/or professional cleaning services, and the prophylaxes available to the workers.

The research project was approved by the Research Ethics Committee (Code 288, Reference 4258). The data to be processed were extracted from the answers given to the questions posed in the surveys. Participants were notified of the survey by email after voluntarily agreeing to the collection of their data.

The data collection was carried out during June 2019. The participants received an email in which they were informed about the survey's objectives, the time allowed to complete the survey (10 min), the voluntary nature of the survey, and the possibility of not completing the survey. This survey also included a section in which the participants had to give their consent prior to completing the survey. The inclusion criteria were centers focused on the diagnosis of pulmonary diseases, both in hospitals and independent research centers, workers with a contract with the center and workers' contact with airborne pathogens. The exclusion criteria were focused on students, non-contract worker, e.g., practices in laboratories or young predoctoral researches, and missing data. The participants who did not complete different parts of the survey did not meet the inclusion criteria and were excluded.

The independent variables included information on the study, laboratory data, work volume, training, information given to workers, and job security. The dependent variable of this study was the incidence of accidents. The data (N = 30) were analyzed using descriptive statistics and the relationships of the qualitative variables. Initially, data normalization was examined using the Shapiro-Wilk test. The results showed that the sample was not normalized ($p < 0.05$), so Mann–Whitney and chi-square U tests were used.

III.2.2. Bibliographic Search

Furthermore, a bibliometric analysis was carried out using the Scopus database. The bibliometric analysis was based on different Medical Subject Heading (MeSH) terms considering the study's objective (Table 2). Additionally, the term "occupational safety" was included in the search to extract more data, although it was related to the MeSH term "occupational health". The Boolean operators used were "OR" and "AND", and the fields were "title", "abstract", and "keywords". After obtaining all the data, SPSS program version 24 (IBM Corporation, Armonk, NY, USA), E.P.I.D.A.T. version. 4.2. (Servicio de Epidemioloxía de la Dirección Xeral de Saúde Pública del Servicio Galego de Saúde (SERGAS), Galicia, Spain) and Excel version 17 (Microsoft Corporation, Redmond, Washington, USA) were used to analyze the information.

The bibliometric analysis was carried out in June 2020 using the following search: (TITLE ({Tuberculosis}) OR ABS ({Tuberculosis}) OR KEY({Tuberculosis}) OR TITLE ({Air Microbiology}) OR ABS ({Air Microbiology}) OR KEY ({Air Microbiology})) AND (TITLE ({occupational health}) OR ABS ({occupational health}) OR KEY ({occupational health}) OR TITLE ({occupational safety}) OR ABS ({occupational safety}) OR KEY ({occupational safety})). The exclusion criteria were articles focused on patients, or on workers that do not come in contact with airborne pathogens or whose work is not carried out in a healthcare environment. Selected studies were those related to healthcare workers and measures regarding occupational safety, with high relevance given to laboratories.

In the first phase, 1159 documents published before 1 June 2020 were identified, focusing on workers, occupational safety, and airborne microbes. In the second phase, screening, 922 studies were excluded based on their titles, abstracts, and keywords. In the third phase, eligibility, exclusions were made based on the timeframe (all previous years up to the last full year (2019)), respiratory diseases related to dust or working conditions, and other work environments, such as coal mines, with 145 documents excluded (Figure 1). For quantitative analysis of the 92 documents, the Mann–Whitney, chi-square U, and Kruskal–Wallis tests were used, based on the Kolmogorov–Wilkins test ($p < 0.05$).

Table 2. MeSH terms and description.

MeSH Terms	Description	Related Terms
Tuberculosis	Any of the infectious diseases of humans and other animals caused by species of *Mycobacterium tuberculosis*	Tuberculoses Kochs Disease Koch's Disease Koch Disease *Mycobacterium tuberculosis* Infection Infection, *Mycobacterium tuberculosis* Infections, *Mycobacterium tuberculosis* Mycobacterium *tuberculosis Infections*
Air microbiology	The presence of bacteria, viruses, and fungi in the air. This term is not restricted to pathogenic organisms.	Microbiology, Air
Occupational health	The promotion and maintenance of physical and mental health in the work environment.	Health, Occupational Industrial Hygiene Hygiene, Industrial Industrial Health Health, Industrial Safety, Occupational Occupational Safety Employee Health Health, Employee

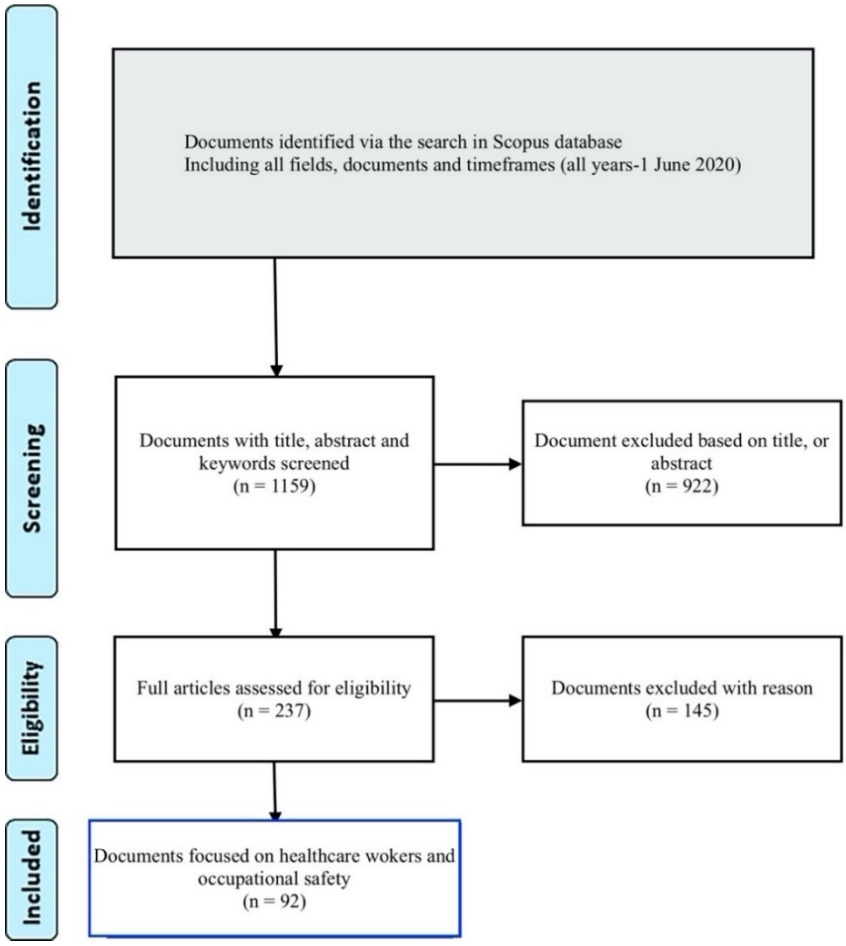


Figure 1. Flow diagram for the selection of articles for bibliometric analysis based on the topic and population

III.3. Results

III.3.1. Results of the Survey

The observational study's initial analysis, based on healthcare workers in laboratories, showed that 23.3% of the participants came from international centers, while 76.7% worked in Spanish centers. In total, 13.3% of the international reference centers were from Europe (Belgium, Sweden, Bulgaria, and Latvia), and 10% were from North and South America (Mexico, Colombia, and the Dominican Republic).

The level of access that professionals have to PPE for their observational studies was analyzed. The results showed that most of the workers did not have all the necessary PPE, such as filtering facepiece (FFP) 1, 2, or 3 masks. It was also observed that international reference centers seemed to have less PPE available (Table 3). Most healthcare workers in laboratories indicated that there was not sufficient PPE to carry out their work, although the workplace measures were safe and secure (Table 4). In Spain, the percentage of workers who considered their work environments to be insufficient was 18.2% in local centers, 100% in regional centers, 57.1% in reference centers, and 100%

in research centers. Moreover, in work environments where tasks related to airborne pathogens are carried out, the same percentages indicated that the available work spaces were unsafe for these tasks.

Table 3. Frequency of responses of the workers.

Questions	Response	International	National			
		Reference Center	Local	Regional	Reference Center	Research Center
Is there sufficient PPE to carry out the work?	Yes	0%	9.1%	0%	0%	0%
	No	100%	90.9%	100%	100%	100%
Are there enough safety and preventative measures?	Yes	85.7%	100%	0%	71.4%	0%
	No	14.3%	0%	100%	28.6%	100%

These workers also indicated how often they and other workers neglected to follow technical safety measures, such as going out in their work clothes, following the procedures for working with Mycobacterium tuberculosis, eating or smoking next to one's workspace, etc. (Table 4).

In terms of training, 100% of the international and national workers described having adequate training. The descriptive analysis showed how 100% of the international centers carried out training regularly as ongoing training. However, at the Spanish level, the results showed that 57.1% of the reference centers' workers did not receive this training regularly. When asked whether they were provided information on preventative measures, 28.6% of international workers in the reference centers considered themselves to have no information. However, at the national level, these values were more favorable for local centers: 18.2% of the workers answered that they had no information compared to 81.8% who considered that they did have such information. In contrast, in the regional centers focused on research, 100% of the workers answered negatively, while for the national reference centers, the distribution of responses was more balanced: 57.1% considered themselves to not have this information, while 42.9% answered that they had received this information.

The number of incidents in the last three years and occupational diseases were analyzed by center. The results showed that at the international level, 14.3% of incidents were reported among the reference center workers, although no worker developed any work-related illness. The data obtained at the national level showed a similar trend, where workers from local and regional centers did not present work-related accidents or illness, while among those surveyed at reference centers, 28.6% declared having suffered some type of accident. A nonparametric analysis was used to determine the differences between groups (those who had suffered an accident and those who had not suffered an accident). The analysis showed differences in the type of laboratory ($p < 0.05$), the numbers of samples processed per year ($p < 0.05$), the collection times of the samples ($p < 0.01$), and ongoing training for

prevention ($p < 0.05$). Based on these results, correlations between the analyzed variables were determined. The analysis focused on relationships with incidents in the last three years that were shown to be linked to the type of laboratory ($p < 0.05$), the type of sample collection ($p < 0.05$), regular training for prevention ($p < 0.001$), and whether workers followed the relevant safety and hygiene protocols ($p < 0.01$).

Table 4. Frequency of occupational safety measures.

Question	Answer	International	National			
		Reference Center	Local	Regional	Reference Center	Research Center
Do you go outside in your work clothes?	Yes	0%	9.1%	0%	0%	0%
	No	100%	90.9%	100%	100%	100%
Do you smoke or eat close to your working area?	Yes	0%	0%	0%	0%	0%
	No	100%	90.9%	100%	100%	100%
Do you clean your workspace following protocol?	Yes	100%	100%	100%	100%	100%
	No	0%	0%	0%	0%	0%
Do you decontaminate following protocol?	Yes	100%	54.5%	100%	57.1%	100%
	No	0%	45.5%	0%	42.9%	0%
Do you wash your hands according to protocol?	Yes	100%	54.5%	100%	28.6%	100%
	No	0%	45.5%	0%	71.4%	0%

III.3.2. Results of the Bibliographic Search

The bibliometric analysis showed that most studies focused on the United States (the USA, with 33 documents), followed by Germany (with eight documents) and the United Kingdom (the UK, with seven documents), with Spain (three documents) and other countries (Belgium and Sweden, with two documents each) poorly represented worldwide (Figure 2). Figure 2 presents the countries of origin of selected publications on the topics (occupational safety, healthcare workers, and airborne pathogens) ($N = 92$), of which most countries, such as the Netherlands and Kenya, provided only one document. The following countries with higher number of documents, including India, Italy, and South Africa, provided an average of five documents (Figure 2).

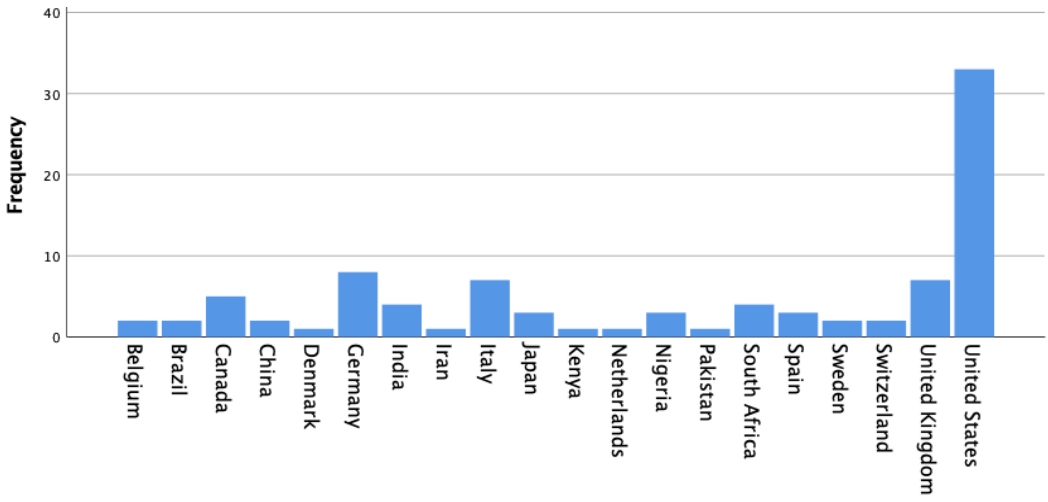


Figure 2. Frequency of documents per country of the bibliometric analysis with a range from one to 33 documents.

The number of publications per year showed significant differences between countries (p = 0.024), with the USA being the greatest producer of publications (p = 0.009). Other aspects analyzed in the previous documents included the citations, for which the cut-off point was the year 2014 (p = 0.037), after which the citations of the publications increased more rapidly, with an effect on the average number of publications per year (Figure 3). Figure 3 shows that many documents were published in 2014 (seven documents), although the trend from that year onward showed a decrease in the number of publications. This change (Figure 3) was similar to what was observed in 2010, when seven documents were published; that number then decreased to three documents a year by 2013.The number of citations per document differed according to the topic (p < 0.001), with a mean of 33 citations. The most commonly cited guidelines focused on prevention health issues among workers, with 848 citations [37]. This report highlights the importance of controlling and preventing tuberculosis for healthcare workers and the general population. For workers, the report highlights the need to control the number of workers in the testing area, provide PPE (especially respiratory protective equipment), implement a respiratory program or protocol, and provide training for healthcare workers on the use of respiratory protection.

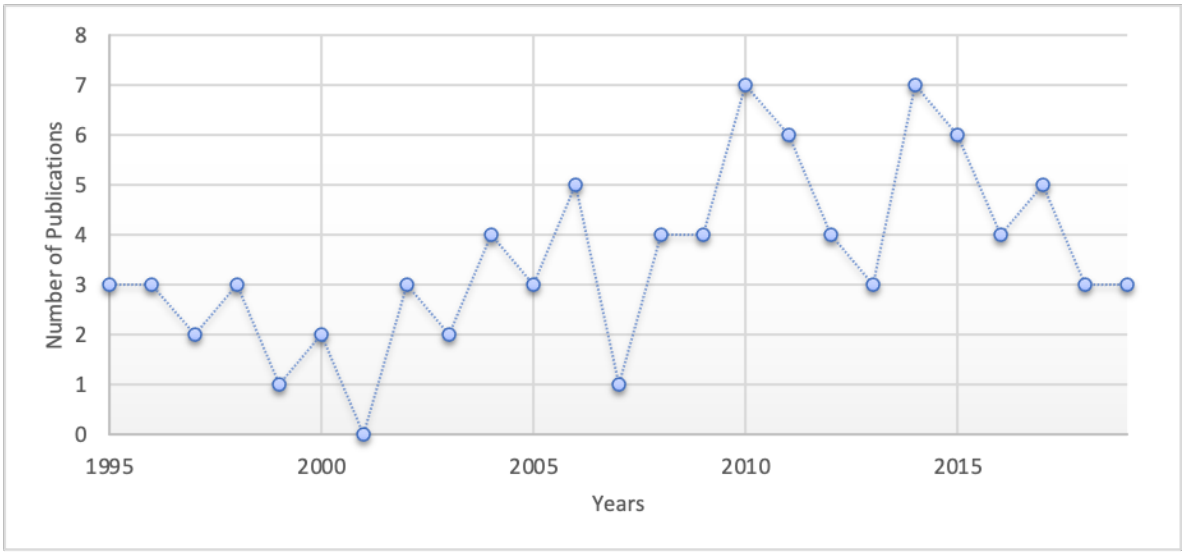


Figure 3. Number of publications per year of the 92 documents from the bibliometric analysis

Based on the results and recommendations, the most commonly cited observational papers were analyzed to determine the different variables and recommendations in the reports [37]. In this case, few studies included laboratories or discussed principles to prevent tuberculosis among workers (Table 5). Only one of the papers (focused on Kenya) analyzed the incidence of tuberculosis alongside one factor, which was training. The next article in terms of number of citations (eight citations) was based on factors related to prevention of tuberculosis or airborne pathogens in the United States in 1997; this study explored the relevant protocols, preventative measures, respiratory protection, and airflow regularity [38]. The results showed the improvement of the studied hospital from 1992 to 1997 ($p < 0.01$) in isolating patients with tuberculosis, assessing airflow regularity, and using PPE following the recommendations of the Centers of Disease Control and Prevention to present transmission in healthcare centers.

Table 5. The five most cited observational articles of the bibliometric analysis.

Title	Year	Country	Sample	Work environment	Variables	Results	Source	Citations
Are healthcare workers in England and Wales at an increased risk of tuberculosis? [39]	1993	United Kingdom	Healthcare workers (*N* = 119)	National Health System	Sex, ethnicity, association with other workers	Crude notification rate among healthcare workers was 11.8 per 100,000 per year	British Medical Journal. (BMJ)	63
Challenges with QuantiFERON-TB Gold Assay for Large-Scale, Routine Screening of U.S. Healthcare Workers [40]	2008–2010	United States	Serial testing results of healthcare workers (*N* = 9153)	National Health System	QuantiFERON-TB Gold In-Tube test, age, sex, QFT results, including the T.B. Antigen, Nil, and Mitogen; and the test run date.	Remaining false positive ($p < 0.001$)	American Journal of Respiratory and Critical Care Medicine	61
Evaluation of Interferon-Gamma Release Assays in the Diagnosis of Recent Tuberculosis Infection in Healthcare Workers [41]	2004–2005	Spain	Testing of healthcare workers (*N* = 147)	National Health System (West)	QuantiFERON-TB GOLD In-Tube and T-SPOT. T.B. in H.C.W.s, comparing the results with a tuberculin skin test (T.S.T.)	A low frequency of B.G.G. vaccination (15.6%); the occupational degree exposure was significant when the outcome was a positive T-SPOT. T.B. result (OR = 2.03)	Plos One	30
Tuberculosis Risk Among Staff of a Large Public Hospital in Kenya [42]	2003–2005	Kenya	Healthcare workers (*N* = 4833)	National Health System	Sex, job designation, years working, household, and guidelines	The time with the patient was liked to tuberculosis (OR = 1.3) Working role ($p = 0.07$)	International Union Against Tuberculosis and Lung Disease	24

High incidence of latent tuberculous infection among South African health workers: An urgent call for action [43]	2008	Kenya	Healthcare workers (*N* = 199)	National Health System	Sociodemographic details, knowledge and risk perceptions of T.B. and L.T.B.I., and training and practice in infection control, I.G.R.A. compared with tuberculin skin test (T.S.T.)	Knowledge and infection control training and practice were associated with a 50–60% reduction in the risk of tuberculosis acquisition	International Union Against Tuberculosis and Lung Disease	23

III.4. Discussion

The analysis of the centers from the observational study alongside the bibliometric analysis provided significant data on the prevalence of tuberculosis, the methods of its diagnosis, related working conditions, and workers' attitudes regarding the relevant protocols.

The Spanish workers observed that there is not full compliance with preventative measures in their centers, as the protocols are not always followed. Meanwhile, the European, North and South American workers more strictly followed the relevant protocols and safety measures, such as decontamination. Another aspect that was different between Spanish and international workers was the prevalence of biological accidents and exposure to airborne pathogens, as exposure was more common among Spanish workers at local centers. These results were consistent with those of other studies, which found that centers with better control and implementation of a set of recommendations have significantly decreased exposure to airborne pathogens and fewer occurrences of biological accidents [44–46]. Another notable result from the observational study was the connection between a higher frequency of accidents and failure to comply with preventative regulations through ongoing training. In fact, one significant finding was the difference between Spanish and international workers regarding ongoing training. This ongoing training in prevention has been described as a necessary activity, especially for laboratory workers [47]. A previous work stated that such training education plays an essential role in identifying and circumventing outbreaks in laboratories [48]. These results match the recommendations [37] put forth by several studies [49,50], indicating the need for worker participation and ongoing training. These results agreed with those of a previous study focused on Level 3 and 4 laboratories around the world, which also indicated the need for training [51]. A previous paper focused on Spain [52] also highlighted the need to improve preventive training among Spanish workers, and how such training plays a key role in maintaining safety measures and preventing accidents. Another study focused on Russia indicated that training is lacking but essential for occupational safety, even more so under extreme or uncomfortable working conditions [53]. These previous studies agree with the reports and reviews from the health field found in the present bibliometric study [54–56], which indicated training as critical. However, contrary to expectations, the bibliometric study did not find a significant number of papers focused on laboratories and the measures taken by their workers. Most papers focused on determining the prevalence of tuberculosis, the proper tests to use, and comparisons between workers [39–43].

Another factor that was important for both Spanish and international workers was the lack of information regarding updates, protocols, or changes in the work environment. Although this

lack of information was not linked to a higher risk of exposure to a biological accident, other studies have noted the importance of such information [57,58]. One paper focused on low-resource settings [59] indicated the need for information management tools to maintain constant feedback and to prevent infections among workers and patients.

Further, the manipulation of samples or cultures was linked to biological accidents and exposure to airborne pathogens in both Spanish and international centers. Samples that can generate aerosols were a significant possible risk factor for acquiring tuberculosis in the laboratory. These results coincide with those of previous studies, which determined that the longer the exposure, the higher the contagion risk. In this sense, previous studies carried out in low-incidence countries indicated how the relevant time to carry out a testing and therefore time of exposure, number of samples manipulated by workers, and type and number tests carried out, must be controlled to prevent exposure among healthcare personnel [57,60]. This risk is also related to sample concentration, the number of samples handled, and the safety measures implemented [48,61]. Another study carried out in 2016 proved that cell cultures of tuberculosis are linked to 22% of work-related contagious diseases, with laboratory technicians the most frequently affected (87%) [51].

Likewise, a large number of workers considered there to be insufficient PPE to carry out the different tasks of their laboratory safely. Among the types of PPE, HEPA filter protection masks play an important role in worker protection, especially against tuberculosis [62]. On the other hand, regarding the perceptions of worker safety and health measures at the European, North and South American levels, a small percentage of workers indicated a lack of such measures, while, in the Spanish context, researchers at the regional level and in the reference and research centers indicated a lack of security measures. This lack of security measures and PPE could be due to the decrease in public investment and purchasing of materials in the last decade, especially in the public sphere [63,64]. These results were similar to a previous review that stated how laboratories workers tough the need to improve the conditions of the work spaces available to workers to carry out their tasks [65]. The concern around such responses is based on the fact that both the CDC and the WHO have indicated the need to improve laboratory environments and employee conditions, highlighting training and the availability of adequate PPE [62].

Despite the significant results and relevance of the different variables analyzed, the bibliometric analysis proved that most studies, which were reviews or reports based on citations, have focused to date on the prevalence of tuberculosis, detection methods, and sometimes work environments. These results seem to align with those of recent studies, which were mainly focused on prevalence and risk factors, such as sex or age [66,67]. Other prior work indicated that

the highest prevalence of work-related contagious illness among laboratory workers (43.4%) was related to a certain age group (women from 30 to 39 years old), which could be related to training [68]. Thus, most works focused on analyzing prevalence rather than the work environment or the worker attitudes. Indeed, the CDC described the relevant preventative factors and how to decrease such prevalence, and WHO highlighted that workers need training and constant updated, and centers should reorganize the workplaces and distribution and updated protocols every decade [34,69,70].

The current research also has limitations. The major limitation of this study is its small sample of laboratories. This research obtained data from laboratories using an observational method that limited the results to the countries that participated, the workers and email surveys invitations sent, and the timeframe used. Also, some demographic data of sample were not included, such as, position in the laboratory, level of studies and time working in the center. Another source of weakness that could have affected the bibliometric analysis is the choice of keywords. This research focused on including concise MeSH terms, which might have delimited the number of publications. Additionally, other terms such as "health work environment" or "laboratories" were not included in the search in order to limit the number of documents, as these extra terms may have resulted in a wider number of publications than desired. Finally, the Boolean operators used, "OR" and "AND", may have included some publications which had different topics of study. However, based on the topic, population, and sample size, including a number of publications with different topics would have produced an insignificant change in the results obtained in this study.

These findings raise intriguing questions regarding the nature and extent of preventative measures taken in healthcare work environments against tuberculosis and other airborne pathogens, especially for laboratory staff. A key practical implication is the need to provide more regular training and adequate PPE for workers.

III.5. Conclusions

The aim of this paper was to assess the occupational safety and preventative measures in laboratories, in both Spain and other countries, and to determine the global differences in occupational safety among healthcare professionals.

The occupational safety and health measures in the studied laboratories were inadequate according to the opinions of the workers, both in Spain and in other European, North and South American countries. One of the most relevant findings is that biological accidents and exposure to airborne pathogens among Spanish and international workers can be linked to ongoing training, the amount of work, and how the workers followed the relevant protocols. Other factors

were also noteworthy, such as the survey responses, since these data illustrated the differences and similarities between Spanish and international contexts, although the opinions of the workers were worse in Spain and were not linked to biological accidents. The results showed that in Spain, the behaviors and hygiene of workers continue to be unsafe and deficient compared to those of other European workers. These results are very interesting, since the Spanish workers expressed poorer opinions of their work environments, such as having smaller workspaces than workers from international centers.

The second major finding was that in most significant previous works, the described variables (e.g., ongoing training) were connected to a higher risk of exposure in observational studies. Another finding that emerged from the bibliometric analysis was that most works focused on countries like the USA or UK, where the incidence of tuberculosis among workers is considered low. Most of the documents from such countries were reviews, with a limited number of observational studies and studies focused on determining occupational safety and health measures. These findings suggest that to decrease the prevalence of tuberculosis and risk among workers, greater compliance with the relevant measures is needed, along with further research that focuses on whether such measures are being followed.

Author Contributions: Conceptualization, A.C.-A. and M.V.-A.; methodology, E.V.-A. and P.A.-M.; validation E.V-A. and P.R.-M.; formal analysis, E.V.-A., P.R.-M., and P.A.-M.; investigation, E.V.-Á., M.V.-A., P.A.-M., and M.D.R.-M.; resources, E.V-A. and P.R.-M.; data curation, P.A.-M. and E.V.-A.; writing—original draft preparation, M.V-A., P.A.-M., and E.V-A.; writing—review and editing, M.V.-A. and A.C.-A.; supervision, M.D.R.-M., and P.A.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the IDEP/Escuela de Doctorado of the University of Cordoba. Also, this manuscript has been funded by the project Contrato OTRI. TEDIZOLID (MERCK SHARP MYCOBACTERIAS.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chiodi, M.B.; Marziale, M.H.P.; Robazzi, M.L.D.C.C. Occupational accidents involving biological material among public health workers. *Rev. Lat. Am. Enferm.* **2007**, *15*, 632–638.
2. Harrison, J. Occupational Safety and Health in the United Kingdom: Securing Future Workplace Health and Wellbeing. *Ind. Health* **2012**, *50*, 261–266.
3. Niemand, A.; Jordaan, A.J.; Minnaar, H. Some international perspectives on legislation for the management of human-induced safety risks. *Jàmbá J. Disaster Risk Stud.* **2016**, *8*, 8.

4. Aiello, A.E. Invited Commentary: Evolution of Social Networks, Health, and the Role of Epidemiology. *Am. J. Epidemiol.* **2017**, *185*, 1089–1092.
5. Rodríguez, E. La salud publica en España en el contexto europeo, 1890–1925. *Revista de Sanidad e Higiene Pública.* **1994**, *68*, 11–27.
6. De Almeida, M.C.M.; da Canini, S.R.M.S.; Reis, R.K.; Toffano, S.E.M.; Pereira, F.M.V.; Gir, E. Clinical treatment adherence of health care workers and students exposed to potentially infectious biological material. *Rev. Esc. Enferm. USP* **2015**, *49*, 259–264.
7. Bianchini, A.; Donini, F.; Pellegrini, M.; Saccani, C. An innovative methodology for measuring the effective implementation of an Occupational Health and Safety Management System in the European Union. *Saf. Sci.* **2017**, *92*, 26–33.
8. Colosio, C.; Mandic-Rajcevic, S.; Godderis, L.; van der Laan, G.; Hulshof, C.; van Dijk, F. Workers' health surveillance: Implementation of the Directive 89/391/EEC in Europe. *Occup. Med. Oxf. Engl.* **2017**, *67*, 574–578.
9. Rafiei, M.; Ezzatian, R.; Farshad, A.; Sokooti, M.; Tabibi, R.; Colosio, C. Occupational Health Services Integrated in Primary Health Care in Iran. *Ann. Glob. Health* **2015**, *81*, 561.
10. Díaz, D.B.; García, R.R.; Baraibar, D.E. Key Corporate Social Responsibility Initiatives: An Empirical Evidence from Spain. In *Key Initiatives in Corporate Social Responsibility: Global Dimension of CSR in Corporate Entities*; Idowu, S.O., Ed.; CSR, Sustainability, Ethics & Governance; Springer International Publishing: New York City, USA, 2016; pp. 71–102, ISBN 978-3-319-21641-6.
11. Kim, Y.; Park, J.; Park, M. Creating a Culture of Prevention in Occupational Safety and Health Practice. *Saf. Health Work* **2016**, *7*, 89–96.
12. Schulte, P.; Vainio, H. Well-being at work—Overview and perspective. *Scand. J. Work. Environ. Health* **2010**, *36*, 422–429.
13. Ncube, F.; Kanda, A. Current Status and the Future of Occupational Safety and Health Legislation in Low- and Middle-Income Countries. *Saf. Health Work* **2018**, *9*, 365–371.
14. Apisarnthanarak, A.; Babcock, H.M.; Fraser, V.J. The effect of nondevice interventions to reduce needlestick injuries among health care workers in a Thai tertiary care center. *Am. J. Infect. Control* **2008**, *36*, 74–75.
15. Hernández, N.M.J.; Montes, V.F.J.; Solano, B.V.M.; Sánchez, M.D.; del Val García, J.L.; Gil, M.E.; Arribas, L.J.L. Accidents with biological material in health care workers in two primary health care areas (1990–1999). *Aten. Primaria* **2001**, *28*, 255–258.
16. Spinazzè, A.; Cattaneo, A.; Cavallo, D.M. COVID-19 Outbreak in Italy: Protecting Worker Health and the Response of the Italian Industrial Hygienists Association. *Ann. Work Expo. Health* **2020**, wxaa044, doi:10.1093/annweh/wxaa044.
17. Friese, C.R.; Veenema, T.G.; Johnson, J.S.; Jayaraman, S.; Chang, J.C.; Clever, L.H. Respiratory Protection Considerations for Healthcare Workers during the COVID-19 Pandemic. *Health Secur.* **2020**, *18*, 237–240.

18. Peng, C.-T.; Wu, T.-Y.; Chen, Y.; Atkin, D.J. Comparing and modeling via social media: The social influences of fitspiration on male instagram users' work out intention. *Comput. Hum. Behav.* **2019**, *99*, 156–167.
19. Vaquero, M.; Gómez, P.; Romero, M.; Casal, M.J. Investigation of biological risk in mycobacteriology laboratories: a multicentre study. *Int. J. Tuberc. Lung Dis.* **2003**, *7*, 879–885.
20. Coelho, A.C.; García Díez, J. Biological Risks and Laboratory-Acquired Infections: A Reality That Cannot be Ignored in Health Biotechnology. *Front. Bioeng. Biotechnol.* **2015**, *3*, 56.
21. Heinzerling, A.; Stuckey, M.J.; Scheuer, T.; Xu, K.; Perkins, K.M.; Resseger, H.; Magill, S.; Verani, J.R.; Jain, S.; Acosta, M.; et al. Transmission of COVID-19 to Health Care Personnel During Exposures to a Hospitalized Patient—Solano County, California, February 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 472–476.
22. Coppeta, L.; Pietroiusti, A.; Neri, A.; Janni, A.; Baldi, S.; Papa, F.; Magrini, A. Prevalence and Risk Factors for Latent Tuberculosis Infection among Healthcare Workers in a Low Incidence Country. *Open Respir. Med. J.* **2019**, *13*, 1–4.
23. World Health Organization Universal health coverage, multisectoral action and social determinants. In *Global Tuberculosis Report 2019*; World Health Organization: Geneva, Switzerland, 2019; pp. 141–163, ISBN 978-92-4-156571-4.
24. Coppeta, L.; Pietroiusti, A.; Balbi, O.; Baldi, S. QuantiFERON-TB Gold Plus evaluation for latent tuberculosis infection among Italian healthcare workers: A cross-sectional study. *Epidemiol. Biostat. Public Health* **2019**, *16*, doi:10.2427/13123.
25. Durando, P.; Sotgiu, G.; Spigno, F.; Piccinini, M.; Mazzarello, G.; Viscoli, C.; Copello, F.; Poli, A.; Ansaldi, F.; Icardi, G. Latent tuberculosis infection and associated risk factors among undergraduate healthcare students in Italy: a cross-sectional study. *BMC Infect. Dis.* **2013**, *13*, 443.
26. Joshi, R.; Reingold, A.L.; Menzies, D.; Pai, M. Tuberculosis among health-care workers in low- and middle-income countries: a systematic review. *PLoS Med.* **2006**, *3*, e494.
27. Navarrete, M.J.H.; Marti, M.C.; Sanchez, E.V.M.; Perez, F.R.; Ilario, A.G.D.; Llorente, J.L.A. Occupational exposures to blood and biological material in healthcare workers. EPINETAC Project 1996–2000. *Med. Clin.* **2004**, *122*, 3, 81–86.
28. Verelst, F.; Kuylen, E.; Beutels, P. Indications for healthcare surge capacity in European countries facing an exponential increase in coronavirus disease (COVID-19) cases, March 2020. *Eurosurveillance* **2020**, *25*, 2000323.
29. Huh, S. How to train health personnel to protect themselves from SARS-CoV-2 (novel coronavirus) infection when caring for a patient or suspected case. *J. Educ. Eval. Health Prof.* **2020**, *17*, 10.
30. Ferioli, M.; Cisternino, C.; Leo, V.; Pisani, L.; Palange, P.; Nava, S. Protecting healthcare workers from SARS-CoV-2 infection: Practical indications. *Eur. Respir. Rev.* **2020**, *29*, 200068.
31. Bahl, P.; Doolan, C.; de Silva, C.; Chughtai, A.A.; Bourouiba, L.; MacIntyre, C.R. Airborne or Droplet Precautions for Health Workers Treating Coronavirus Disease 2019? *J. Infect. Dis.* **2020**, jiaa189, doi:10.1093/infdis/jiaa189.

32. Seidler, A.; Nienhaus, A.; Diel, R. Review of Epidemiological Studies on the Occupational Risk of Tuberculosis in Low-Incidence Areas. *Respiration* **2005**, *72*, 431–446.
33. Kim, S.J.; Lee, S.-H.; Kim, I.; Kim, H.J.; Kim, S.; Rieder, H. Risk of occupational tuberculosis in National Tuberculosis Programme laboratories in Korea. *Int. J. Tuberc. Lung Dis.* **2007**, *11*, 138–142.
34. Ridderhof, J.C.; van Deun, A.; Kam, K.M.; Narayanan, P.R.; Aziz, M.A. Roles of laboratories and laboratory systems in effective tuberculosis programmes. *Bull. World Health Organ.* **2007**, *85*, 354–359.
35. Health and Safety Executive Coronavirus (COVID-19): Update. Available online: https://www.hse.gov.uk/toolbox/ppe.htm# (accessed on 11 May 2020).
36. United States Department of Labor Laboratory Workers and Employers. Available online: https://www.osha.gov/SLTC/covid-19/laboratory.html (accessed on 11 May 2020).
37. Jensen, P.A.; Lambert, L.A.; Iademarco, M.F.; Ridzon, R. Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005. *Morb. Mortal. Wkly. Rep.* **2005**, *54*, 1–141.
38. Fuss, E.P.; Israel, E.; Baruch, N.; Roghmann, M.-C. Improved tuberculosis infection control practices in Maryland acute care hospitals. *Am. J. Infect. Control* **2000**, *28*, 133–137.
39. Meredith, S.; Watson, J.M.; Citron, K.M.; Cockcroft, A.; Darbyshire, J.H. Are healthcare workers in England and Wales at increased risk of tuberculosis? *BMJ* **1996**, *313*, 522–525.
40. Slater, M.L.; Welland, G.; Pai, M.; Parsonnet, J.; Banaei, N. Challenges with QuantiFERON-TB Gold Assay for Large-Scale, Routine Screening of U.S. Healthcare Workers. *Am. J. Respir. Crit. Care Med.* **2013**, *188*, 1005–1010.
41. Casas, I.; Latorre, I.; Esteve, M.; Ruiz-Manzano, J.; Rodriguez, D.; Prat, C.; García-Olivé, I.; Lacoma, A.; Ausina, V.; Domínguez, J. Evaluation of Interferon-Gamma Release Assays in the Diagnosis of Recent Tuberculosis Infection in Health Care Workers. *PLoS ONE* **2009**, *4*, e6686.
42. Galgalo, T.; Dalal, S.; Cain, K.P.; Oeltmann, J.; Tetteh, C.; Kamau, J.G.; Njenga, M.K.; Breiman, R.F.; Chakaya, J.M.; Irimu, H.M.; et al. Tuberculosis risk among staff of a large public hospital in Kenya. *Int. J. Tuberc. Lung Dis.* **2008**, *12*, 949–954.
43. McCarthy, K.M.; Scott, L.E.; Gous, N.; Tellie, M.; Venter, W.D.F.; Stevens, W.S.; Van Rie, A. High incidence of latent tuberculous infection among South African health workers: An urgent call for action. *Int. J. Tuberc. Lung Dis.* **2015**, *19*, 647–653.
44. Beggs, C.B.; Kerr, K.G.; Donnelly, J.K.; Sleigh, P.A.; Mara, D.D.; Cairns, G. An engineering approach to the control of Mycobacterium tuberculosis and other airborne pathogens: A UK hospital based pilot study. *Trans. R. Soc. Trop. Med. Hyg.* **2000**, *94*, 141–146.
45. Kato, M.; Osuga, K.; Fujita, M.; Jimba, M. Ensuring tuberculosis infection control to support greater involvement of people living with HIV in health care. *Int. Health* **2011**, *3*, 221–225.
46. Aliabadi, A.A.; Rogak, S.N.; Bartlett, K.H.; Green, S.I. Preventing Airborne Disease Transmission: Review of Methods for Ventilation Design in Health Care Facilities. *Adv. Prev. Med.* **2011**, *2011*, 124064.
47. Giménez-Marín, A.; Rivas-Ruiz, F.; García-Raja, A.M.; Venta-Obaya, R.; Fusté-Ventosa, M.; Caballé-Martín, I.; Benítez-Estevez, A.; Quinteiro-García, A.I.; Bedini, J.L.; León-Justel, A.; et al. Assessment of

patient safety culture in clinical laboratories in the Spanish National Health System. *Biochem. Medica* **2015**, *25*, 363–376.

48. Peng, H.; Bilal, M.; Iqbal, H. Improved Biosafety and Biosecurity Measures and/or Strategies to Tackle Laboratory-Acquired Infections and Related Risks. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2697.
49. Jones, R.M.; Brosseau, L.M. Aerosol transmission of infectious disease. *J. Occup. Environ. Med.* **2015**, *57*, 501–508.
50. Sydnor, E.R.M.; Perl, T.M. Hospital epidemiology and infection control in acute-care settings. *Clin. Microbiol. Rev.* **2011**, *24*, 141–173.
51. Wurtz, N.; Papa, A.; Hukic, M.; Di Caro, A.; Leparc-Goffart, I.; Leroy, E.; Landini, M.P.; Sekeyova, Z.; Dumler, J.S.; Bădescu, D.; et al. Survey of laboratory-acquired infections around the world in biosafety level 3 and 4 laboratories. *Eur. J. Clin. Microbiol. Infect. Dis.* **2016**, *35*, 1247–1258.
52. Rojo-Molinero, E.; Alados, J.C.; de la Pedrosa, E.G.G.; Leiva, J.; Pérez, J.L. Safety in the Microbiology laboratory. *Enferm. Infecc. Microbiol. Clin.* **2015**, *33*, 404–410.
53. Dudarev, A.A.; Karnachev, I.P.; Øyvind Odland, J. Occupational accidents in Russia and the Russian Arctic. *Int. J. Circumpolar Health* **2013**, *72*, doi:10.3402/ijch.v72i0.20458.
54. Turin, T.; Ahmed, S.; Vaska, M. Conducting a Literature Review in Health Research: Basics of the Approach, Typology and Methodology. *J. Natl. Heart Found. Bangladesh* **2016**, 5, 44–51.
55. Gopalakrishnan, S.; Ganeshkumar, P. Systematic Reviews and Meta-analysis: Understanding the Best Evidence in Primary Healthcare. *J. Fam. Med. Prim. Care* **2013**, *2*, 9–14.
56. Altman, D.; Simera, I. Using Reporting Guidelines Effectively to Ensure Good Reporting of Health Research. In *Guidelines for Reporting Health Research: A User's Manual*; Wiley: Hoboken, Nueva Jersey, USA, 2014; pp. 32–40.
57. Parrish, N.M.; Carroll, K.C. Role of the Clinical Mycobacteriology Laboratory in Diagnosis and Management of Tuberculosis in Low-Prevalence Settings. *J. Clin. Microbiol.* **2011**, *49*, 772.
58. Bowen, R.; Benavides, R.; Colón-Franco, J.M.; Katzman, B.M.; Muthukumar, A.; Sadrzadeh, H.; Straseski, J.; Klause, U.; Tran, N. Best practices in mitigating the risk of biotin interference with laboratory testing. *Clin. Biochem.* **2019**, *74*, 1–11.
59. Ombelet, S.; Ronat, J.-B.; Walsh, T.; Yansouni, C.P.; Cox, J.; Vlieghe, E.; Martiny, D.; Semret, M.; Vandenberg, O.; Jacobs, J. Clinical bacteriology in low-resource settings: Today's solutions. *Lancet Infect. Dis.* **2018**, *18*, e248–e258.
60. Weinstein, R.A.; Singh, K. Laboratory-Acquired Infections. *Clin. Infect. Dis.* **2009**, *49*, 142–147.
61. Jilcha, K.; Kitaw, D. Industrial occupational safety and health innovation for sustainable development. *Eng. Sci. Technol. Int. J.* **2017**, *20*, 372–380.
62. Parsons, L.M.; Somoskövi, Á.; Gutierrez, C.; Lee, E.; Paramasivan, C.N.; Abimiku, A.; Spector, S.; Roscigno, G.; Nkengasong, J. Laboratory Diagnosis of Tuberculosis in Resource-Poor Countries: Challenges and Opportunities. *Clin. Microbiol. Rev.* **2011**, *24*, 314.
63. Gagliardi, D.; Marinaccio, A.; Valenti, A.; Iavicoli, S. Occupational Safety and Health in Europe: Lessons from the Past, Challenges and Opportunities for the Future. *Ind. Health* **2012**, *50*, 7–11.

64. de la Fuente, V.S.; López, M.A.C.; González, I.F.; Alcántara, O.J.G.; Ritzel, D.O. The impact of the economic crisis on occupational injuries. *J. Saf. Res.* **2014**, *48*, 77–85.
65. Kimman, T.G.; Smit, E.; Klein, M.R. Evidence-based biosafety: a review of the principles and effectiveness of microbiological containment measures. *Clin. Microbiol. Rev.* **2008**, *21*, 403–425.
66. Sadaf, R.; Munir, T.; Farrukh, S.; Abbasi, S. Prevalence of latent tuberculosis infection in healthcare workers in tertiary care hospitals of Pakistan. *Pak. J. Med. Sci.* **2020**, *36*, 198–202.
67. Erawati, M.; Andriany, M. The Prevalence and Demographic Risk Factors for Latent Tuberculosis Infection (LTBI) Among Healthcare Workers in Semarang, Indonesia. *J. Multidiscip. Healthc.* **2020**, *13*, 197–206.
68. Zhang, X.; Jia, H.; Liu, F.; Pan, L.; Xing, A.; Gu, S.; Du, B.; Sun, Q.; Wei, R.; Zhang, Z. Prevalence and Risk Factors for Latent Tuberculosis Infection among Health Care Workers in China: A Cross-Sectional Study. *PLoS ONE* **2013**, *8*, e66412.
69. Shinnick, T.M.; Iademarco, M.F.; Ridderhof, J.C. National plan for reliable tuberculosis laboratory services using a systems approach. Recommendations from CDC and the Association of Public Health Laboratories Task Force on Tuberculosis Laboratory Services. *Morb. Mortal. Wkly. Rep.* **2005**, *54*, 1–12.
70. Centers for Disease Control and Prevention (CDC) Plan to combat extensively drug-resistant tuberculosis: Recommendations of the Federal Tuberculosis Task Force. *Morb. Mortal. Wkly. Rep.* **2009**, *58*, 1–43.

Chapter IV. Preventing tuberculosis among populations and healthcare workers in Spain and Germany: a comparison of protocols

Chapter IV. Preventing tuberculosis among populations and healthcare workers in Spain and Germany: a comparison of protocols

Esther Vaquero-Álvarez[1] Pilar Ruiz-Martínez [1], Manuel Vaquero-Abellán[2,3], María Dolores Redel Mecías [4] and Pilar Aparicio-Martínez [2,3]

[1] Simulation models in energy, transport, physics, engineering, occupational hazard researcher Group, Junta de Andalucía, and Dpt. Applied Physics, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, Spain; z12vaalm@uco.es, fa1pepeg@uco.es; fa1majip@uco.es

[2] GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; n32apmap@uco.es (P.A.M.); en1vaabm@uco.es (M.V.A.);

[3] Departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, Córdoba, Spain; n32apmap@uco.es (P.A.M.); en1vaabm@uco.es (M.V.A.);

[4] Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ig1remam@uco.es (M.D.R.-M.)

Abstract: Tuberculosis (TB) continues to be one the preventable top ten cause of death. The concerning issue is that around 10 million people suffered from TB. Germany has lower rate of infection and incidence of TB that Spain. This prevalence of TB is a risk for healthcare workers. Based on the World Health Organization (WHO) that highlighted the importance of periodically review the national programs especially the plans and policies based on monitoring, reporting and recommending, the current study had as objective the determination of the differences of preventing TB between the two European countries via the German and Spanish prevention protocols. Some of the conclusion were how both Spain and Germany have committed themselves to establishing guidelines for TB prevention in order to achieve the goals proposed by WHO at the global level. Both countries agree on case reporting, chemoprophylaxis, and treatment of latent tuberculosis. And it is essential for TB control to improve the level of knowledge of practitioners and health care personnel, but of course also of those affected with their environment.

Keywords: tuberculosis; prevention; occupational safety; European standards.

IV.1. Introduction

Tuberculosis (TB) is a bacterial infection caused by *Mycobacterium tuberculosis*, which is considered a level 3 organism based on the risk to pathogenetic capacity [1]. This member of the *Mycobacteriaceae family* is aerobe pathogen, that grows slowly in culture, whose prevalence

continue to flourish [2]. According to the World Health Organization (WHO), TB is one of the preventable top ten cause of death, being highly contagious and one of the older diseases suffered by humans [3]. TB, as an airborne pathogen, is highly contiguous since it introduces and culture in the lung structure and spreads from person to person through air. This pathway allows to the pathogen to be transmitted via aerosolized when an infected individual coughs, sneezes, or speaks[2]. Most of the individuals that suffered from TB, do not present any symptomatology, being defined as latent tuberculosis infection (LTBI). These individuals are not contiguous to others but have a high risk of developing TB and posterior pulmonary problems or death. Active TB disease can develop within a few weeks following exposure or manifest years or even decades later. The treatment of this active disease is a highly complex and ever-evolving topic that goes well. The concerning issue is that around 10 million people suffered from TB, representing a quarter of the global population [4], and up to 1.7 billion people have being in contact with *Mycobacterium tuberculosis* and will developed this disease [1].

Currently, it was estimated that only in European countries the incidence is decreasing but continues to be 28 (24-34) per 100,000 individuals suffer from it and most of these individuals have the LTBI [3,5]. Moreover, only in 2015 up to 2 billion people around the world underwent from a latent state of TB [3], being higher than desirable in low-risk countries, such as Italy [6]. The European Centre for Disease Prevention and Control (in English ECDC) and the WHO European Region showed that the incidence of TB, even though in a decreasing tendency during the last four years (-3.7% in TB incidence in Europe)[7], had higher levels in countries like Spain, especially among younger individuals (0-4 years old)[7]. In opposition countries such as Germany has lower rate of infection and incidence of TB that the mean of the European Region and countries like Spain (Table 1)[7,8]. In fact, Germany has had one of the lowest incidence rates of Europe, which has increased via the migratory flows, but compared to countries like Spain continues to be lower than the mean of European countries [9]. In contrast, in Spain the rate has been decreasing in the last ten and four years, but the incidence depends on the native population more than the migratory flows, which seems to indicate some discrepancies in the prevention or treatment compared to Germany[7].

Table 1. Rate per 100,000 individuals of TB from the European Region, Spain and Germany [7,8]

	Standardized death rate in 2017	**Estimated death rate in 2018**	**Estimated incidence in 2018**	**TB cases in Native population in 2018**	**TB case notifications in 2018**	**New and relapses notification**

						rate of TB in 2018
European Region (28 countries)	-	0.7	11.2	63.1	10.2	27.9
Germany	0.31	0.4	7.3	25.3	6.6	6.4
Spain	0.48	0.6	9.4	56.6	10.0	9.6

These differences inside the European Region seemed to be linked to the screening, migration rates, the creation of programs for latent TB, treatment [10] and following up protocols [11]. An example of the difference between countries is that according to a last report, only two countries reported in 2018 a treatment protocol for LTBI in childhood[10], even though ECDC and WHO recommended that all the European (EU/EEA) countries should have one. This is only an example of improvements that can be made to decrease the incidence, death or treatment rate of people with TB. In fact, WHO and ECDC has stated that an appropriate diagnosis and treatment with antibiotics, vaccination, follow up and early screening programs the rate would be much lower [12]. Additionally, the prevalence of TB and LTBI constitute a risk for healthcare workers (HCWs) and therefore are routinely screened for LTBI, an example of this is showed in study focused on German workers with 3.86% higher risk than other workers [13,14]. In this sense, the prevention or reduction of the risk to healthcare workers via the decrease and control of epidemics in the populations is one of the goal of the occupational safety[15], as seen in the current pandemic of Covid-19[16].

According to the WHO, it is highly important to periodically review the national programs especially the plans and policies, and associated activities, based on monitoring, reporting and recommending [3]. Based on the previous statement and relevance of reviewing the national programs, the current study has as objective the determination of the differences of preventing TB between the two European countries via the German and Spanish prevention protocols [17,18], and it is discussed whether the recommendations made by WHO are followed.

IV.2. The epidemiological surveillance

The epidemiological surveillance focused on the early detection and diagnose of TB and even the multidrug-resistance (MDR) and extensively drug-resistant (XDR) of TB, including the monitorization and assessment of national programs to avoid the new cases [19,20]. Although the WHO has stated the relevance of epidemiological surveillance, only 60 % of countries have

accessible reports and data regarding TB. In the European Region, TB surveillance level is responsibility of the ECDC and the WHO European Region that coordinate their activities and build a joint annual aggregated report based on information provided by the European Member States. Epidemiological surveillance plays a decisive role in understanding and characterizing the presentation of this disease in the population and in having the information necessary to establish measures to control and prevent its incidence in the community [21]. The data collected in the surveillance activity allows to describe the trend and evolution of incidence, drug resistance, to identify high-risk groups and areas where transmission occurs and to identify outbreaks. In this sense, the ECDC showed from the epidemiological data a decreasing tendency in Europe, but when compared Germany and Spain (Figure 1) the significance between the rate of notification is clear. The Figure 1 shows how the Spanish population in all ranges age, except from 15 to 25 years old, have higher incidence of TB.

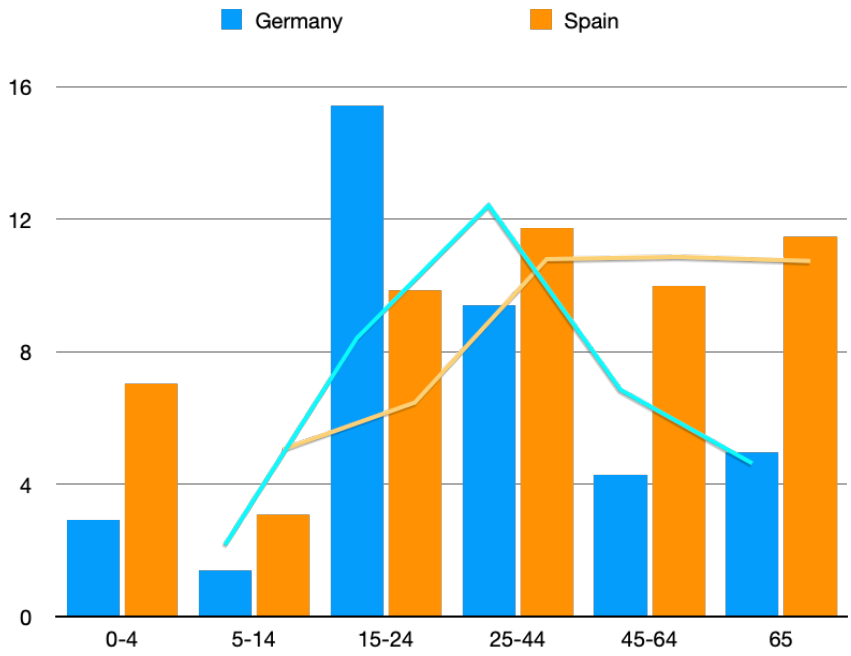


Figure 7. Differences between Spain and Germany regarding the notification rate per 100,000

When compared the protocols of surveillance of both countries, the Spain protocol, regulated by Order SSI 445/2015 of 9 March which is an amend of the annexes to the Royal Decree creating RENAVE in 1995 concerning the form of surveillance of notifiable diseases, established that for TB the individual declaration of each diagnosed case accompanied by the information from the survey is needed[17].Since this Royal Decree and protocol, and posterior data following the year 1999, the number of new cases has significantly decreased (Spearman's correlation= -0.51; *p*-value=0.027) (Figure 2).

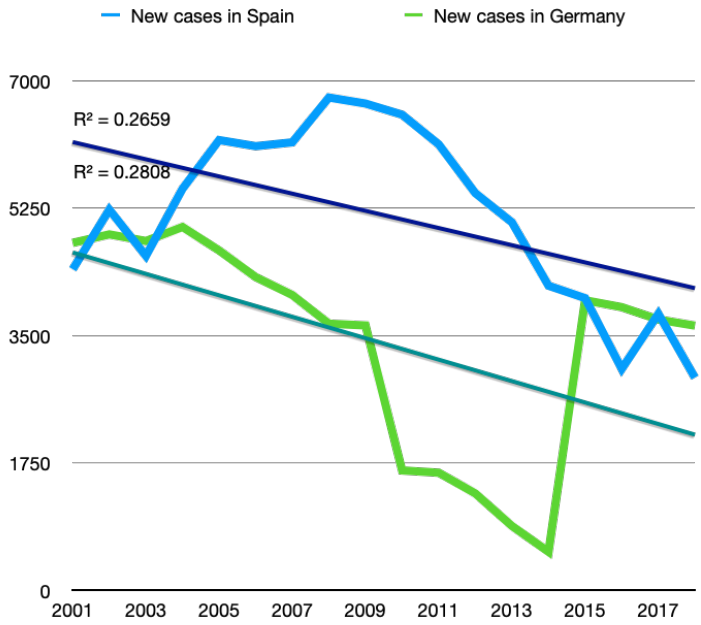


Figure 8. Rate of new cases from 100,000 in Spain

In the case of Germany, with the introduction of the Infection Protection Act, a new quality of tuberculosis control was achieved in Germany. The data of the individual case reports are consolidated on the level of the federal states and on the national level. They allow a continuous analysis and early assessment of the development of tuberculosis in Germany. These evaluations are summarized in the annual "Report on the Epidemiology of Tuberculosis in Germany", which is also available electronically on the RKI website. Both reports must be submitted to the public health department within 24 hours of the time at which they become known[23]. This code seems to significantly decrease the cases (Correlation= -0.51; *p*-value=0.027), although there was an increased from 2014 to 2015 of 3,457 rate per 100,000 inhabitants, being in 39.3% of the new cases native from German and 31.9% in 2015[22]. According to the latest data published for 2018, the number of cases was 4,389 with a rate per 100,000 inhabitants of 9.39%. To these cases, 260 more imported cases should be added. These data show a downward trend, since the number of cases in 2017 was 4,573 (rate per 100,000 inhabitants of 9.43) and in 2016, 4,934 cases [22]. In 2019, 4,791 tuberculosis were registered in Germany, which corresponds to an incidence of 5.8 new cases per 100,000 inhabitants. After a significant increase in 2015, the numbers first started to decrease in 2017 and stagnated in 2018. Again in 2019 a significant decrease was achieved, the incidence has decreased by 12.8% compared to the previous year[24]. In this period of time, the results showed differences between age and origin, being the new cases of TB more prevalent between young people with nationals different from Germany (with a maximum incidence of 66.5 in of the 20-24 age group)[23].

In the case of healthcare workers there are data for both Spain and Germany that showed different results for LBTI. The last article in Spain [25] showed the prevalence increased 18.5% from 1988 to 2007, indicating a significant increased which differs from the data of the population. In the case of Germany, the prevalence was 7.2%, being the prevalence higher in workers older than 50 years old (22%), nurses (4.5%) and physicians (10.8%)[26]. The results showed that Spanish HCWs were at higher risk than the German HCWs, which could be as a result of the surveillance of TB in German HCWs[27]

IV.3. Diagnostic, contact and MDR/XDR

IV.3.1. Procedure for the diagnosis

The immunological test procedures are based on the detection of a cellular type IV reaction to tuberculin or the in vitro reaction of T lymphocytes to selected antigens of M. tuberculosis. A reliable differentiation between active disease and latent tuberculosis infection is not possible with these methods. They are primarily used to detect LTBI. For the diagnosis of the active disease, they play only a minor role. The tuberculin skin test is a diagnostic test for the detection of tuberculosis [28]. The tuberculin skin test is used to check the reaction of T-lymphocytes to antigens of Mycobacterium tuberculosis. For this purpose, standardized, purified tuberculin extract is administered intracutaneously. The skin reaction is then tested. Previously performed tests such as the Pirquet sample or the Tinetest (stamp test) were abandoned[28,29].

In Germany and Spain, the Mendel-Mantoux method is used, and since 2005, the tuberculin PPD RT23 SSI of the National Serum Institute in Copenhagen has been used as the test substance. PPD stands for "purified protein derivative", an antigen mixture of tuberculosis pathogens produced according to internationally defined standards. If there is an immune reaction against tuberculosis, a delayed immune reaction (type IV) occurs within 72 hours after intracutaneous injection of the test substance, in which T cells react to the antigen and cause a local reaction. This screening test was based on 2 tuberculin units of PPD RT23 injected intracutaneously in 0.1 ml free water on the volar side of the forearm. This is equivalent to the injection of the 10 tuberculin units of Behring tuberculin that were previously used. The injection site is indicated by marking. The tuberculin skin test is read after 72 hours. A positive test result is obtained if the induration is greater than 5 mm. A reddening alone is meaningless. It should be noted that the skin test is almost always positive in patients with a BCG vaccination and that in this case tuberculosis can only be assumed if the induration is more pronounced (10-15 mm) (see also influencing factors). This test has a high sensitivity with limited specificity, with a number of false-positive results

larger than desirables because of numerous influencing factors. Based on this, the tuberculin skin test is only appropriate for screening in populations with a high prevalence.

In Germany, for example, it is only of limited suitability for screening and later diagnosis requires the interferon-gamma-release assay, which is considered the golden standard in terms of sensitivity and specificity[30]. This test is a valuable diagnostic tool, especially for patients with a positive tuberculin skin test but unclear clinical or radiological findings. The γ interferon test can also provide clarity in cases of doubt about a positive skin test, for example in patients who have been vaccinated with BCG. With the γ interferon test, it is also possible to quickly and relatively reliably test for latent tuberculosis or a possible infection after exposure to tuberculosis patients. As a sole examination they are not suitable to prove or rule out tuberculosis safely[6,31,32]. Both protocols (Spanish and German) [17,18] agree on this statement, nevertheless, this test requires specific diagnostic laboratories focused on airborne pathogens, like tuberculosis, which limited the number of samples that can be tested [14,33].

Both, the tuberculin and interferon-gamma-relase assay are adequate option for the diagnosis in the case of healthcare professionals, whose risk is higher than other groups. This risk present for these professionals, from nurses to the laboratory technicians, implies a necessity of further control, follow up and adequate personal protective equipment[1,6,13]. Although a previous German study indicated that the screening of LTBI could be reduced to HCWs in unprotected contact with infectious patients or materials, it seems that preventive medical check-ups are still needed [27,34].

Tuberculin (PT) tests according to the Mantoux technique and the IGRA (Interferon-Gamma Release Assay) are widely used in both Germany and Spain to identify infection. Germany and Spain agree in describing the disadvantages of the tuberculin test: problems of sensitivity (poor or non-existent response in patients with altered cellular immunity) and specificity. The interpretation of THT results can be complicated by a possible cross-reaction due to infection with non-tuberculous mycobacteria (NTM) or a previous BCG vaccination, which can lead to false positive results. IGRAs show a better specificity than the THT test with at least comparable sensitivity, since BCG vaccination and infection by most NTMs (except M. kansasii, M. marinum, M. szulgai, M. flavescens and M. gastrii) does not lead to a false positive reaction to the test result [17,18].

IV.3.2. Contact service and survillance

The contact and posterior feedback is a main pillar in preventing the spread of TB or to correctly treat the people suffered from it [7,28]. In both protocols [17,18] the importance of contact persons is stressed. Contact persons are subject to the usual control measures required in the context of environmental examinations and attention must be paid to symptoms suspected of tuberculosis, in particular coughing of unknown cause. Particularly in the case of persons belonging to one of the particularly vulnerable groups (e.g. HIV-infected persons), tuberculosis should be included in the differential diagnosis at an early stage. Also, individuals precedent from countries or regions with higher rates of TB, such as Asia or Africa, whose prevalence of LTBI or TB are up to 80% in the population and have increased the prevalence and the rate of notification in European countries, like Germany[9,35].

IV.3.3. MDR-TB and XDR-TB

MDR-TB is tuberculosis caused by pathogens that are resistant to two or more first-line tuberculostatics. MDR-TB is caused by tuberculosis bacteria that are resistant to isoniazid and rifampicin, for example[21]. If the tuberculosis pathogens are also resistant to second line tuberculostatics, one speaks of XDR-TB. A tuberculosis patient develops MDR-TB if, during treatment, the first line antituberculotics are incorrectly dosed or taken and thus become ineffective (lack of combination therapy). People with MDR-TB can be infectious and pass on the resistant pathogens to other people. Active ingredients for the treatment of MDR-TB are second line tuberculostatics and reserve antibiotics such as bedaquiline and delamanide [36].

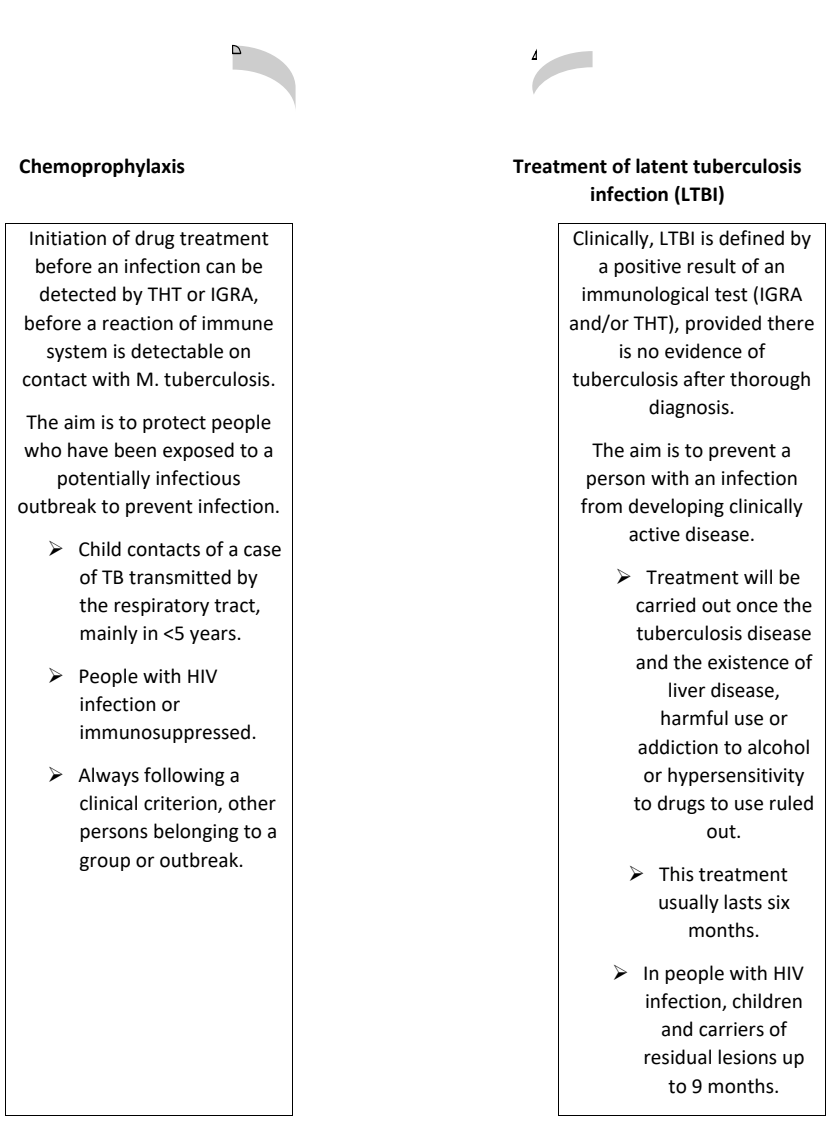


Figure 9. Preventive treatment of latent TB

MDR/XDR tuberculosis represents a major challenge for tuberculosis control in Germany and Spain, as well as the rest of Europe[36], and the interpretation of the microbiological results is complex (Figure 3). In order to choose the most useful therapeutic scheme for these patients, the most up-to-date recommendations will be followed, which classify the available drugs into three groups and ordered according to recent evidence regarding the balance of effectiveness and safety.

Drug resistance and MDR-TB is mainly found in patients born abroad, but to a relevant extent also in adults born in Germany and also in children. Almost one in five of those affected is in a Country of the Eastern Mediterranean Region (18.8 %) born and every sixth sick person came

from the African region (16.9 %). The countries of other WHO regions are currently playing in Germany epidemiologically only a minor role[24].

Persons born in a foreign country have a higher risk of developing resistant TB, this applies especially to the origin from countries of former Soviet Union (especially the Russian Federation and Kazakhstan). Due to the changed migration flows, however, there are now Germany, the African countries of birth, such as Somalia and Eritrea, also play an important role with regard to drug-resistant TB. To a small extent, however, native patients of complex-resistant tuberculosis are also affected. Therefore, the use of rapid resistance methods, not only, but especially when resistance is suspected, is of great meaning[23,37]. The treatment, period of time and duration was analyzed and compared (Table 2) showing differences between countries that have further explained as follows.

Table 2. Treatment used in Germany and Spain

Regimes	Country	Dose	Maximal dose	Duration
INH	Spain/Germany	Adults: 5 mg/kg Children: 10 mg/kg	300 mg	9 months
RMP	Spain/Germany	Adults 10 mg/kg Children 15 mg/kg	600 mg	4 months
INH + RMP	Spain/Germany	Analogue to the respective monotherapy		3-4 months
INH + Rifapentine (neither in Spain nor in Germany commercialized)	**Spain**	**INH**: >12 years 15 mg; 2-11 years 25 mg. **Rifapentine:** 10-14 kg: 300 mg 14,1-25 kg: 450 mg 25,1 – 32 kg: 600 mg 32,1-50 kg: 750 mg	900 mg each plus 900 mg once a week	3 months

	>50 kg: 900 mg
Germany	Children ≥ 2 years, Rifapentine dose based on weight approx.. 25 mg/kg (900 mg maximum+ INH 25 mg/kg (900 mg maximum) during 3 months WHO recommendation

According to the German Tuberculosis Prevention Guide **[18],** chemoprophylaxis in adults should be treated in this way: "Chemoprophylaxis is carried out in adults with INH 300 mg/d, unless resistance to INH is known in the index case. At the earliest eight weeks after the last contact with the infectious index case, the person must be tested again for LTBI (IGRA). If the test remains negative and the contact person is symptom-free, the INH therapy should be stopped. If the IGRA is positive, chemoprophylaxis is continued for a total period of nine months after exclusion of organ tuberculosis as preventive chemotherapy to prevent progression to tuberculosis. For children the chemoprophylaxis is done with INH (recommended dosage 10 mg/kg body weight (KG). Eight weeks after the last contact, in exposed newborns and young infants after the age of 3 months, the TB-exposed person should be tested again if the initial test result is negative."

As for the recommendations in Spain [17] "The PT is repeated at 8-12 weeks. If it is negative, the treatment will be interrupted, and if it is positive, it will be continued, previously ruling out the disease, until the guideline is completed. Chemoprophylaxis consists of the administration of 300 mg/day of isoniazid in adults and 10 mg/kg in children, during a period of 8 to 12 weeks".

The chemoprevention is the therapy of LTBI which is indicated as the treatment of demonstrably infected patients with the aim of reducing the rate of later diseases through reactivations. Chemopropylaxis means whereas the prophylactic treatment of exposed persons, who have not yet been infected or whose infection is still is not detectable. Meanwhile, the chemoprophylaxis is the administration of tuberculosis drugs at the earliest possible time after exposure, when no immunological reaction in the form of a positive tuberculin skin test or a positive IGRA can be detected. It is intended to prevent the onset of a new infection in risk persons (e.g. children under five years and patients under immunosuppression) and is carried

out with INH-monotherapy. Before this measure, an active disease must be radiologically excluded. If the IGRA or THT is negative after eight weeks of therapy, the prophylaxis can be terminated. If the result is positive, the therapy is continued as prevention for a total of nine months[28,37].

IV.5. Standard treatment in new TB cases

The treatment of new cases of TB is similar to the previous described [28,37,38]. Likewise, the standard treatment in new TB cases is as follows in Spain: "The standard guideline for any initial patient without suspected resistance will consist of two months with R, H, pyrazinamide (Z) and ethambutol (E), followed by a four-month maintenance with the first two drugs". And in Germany the procedure is the same: "The six-month standard therapy necessarily requires the use of the substances INH, RMP, PZA and EMB". In both countries the indications and descriptions are following the recommendation made by the WHO[21]. The standard short-term therapy for pulmonary tuberculosis in adults is a 6-month chemotherapy, in which INH, RMP, PZA and EMB are given for the first two months (initial phase) and further treatment with INH and RMP is given for the following four months (stabilisation or continuity phase) (Table 3). If full drug sensitivity has been demonstrated, triple treatment (INH, RMP, PZA) may be considered in individual cases in the initial phase. In children, too, therapy for uncomplicated pulmonary tuberculosis is started in this way because of the pauzibacillary, i.e. low-bacterial characteristics[28,37,38].

Table 3. Treatment used in Germany and Spain

Initial phase	**Duration (months)**	**Continuity phase**	**Duration (months)**
INH, RMP, PZA, EMB	2	INH, RMP	4

IV.5.1. BCG Vaccine

With regard to the BCG vaccine, the reasons for leaving of vaccination were the low risk of *Mycobacterium tuberculosis* infection in Spain, the variable effectiveness of the vaccine against pulmonary TB in adults and the interference of vaccination with tuberculin test.

The BCG vaccination is no longer recommended by the Standing Commission on Vaccination (STIKO) at the Robert Koch Institute in Germany since 1998. This is in line with the

recommendations of the WHO, which has proposed that no general BCG vaccination should be carried out in populations whose risk of infection with tuberculosis is less than 0.1%. The Robert Koch Institute is the central institution of the Federal Government in the field of disease surveillance and prevention. The core tasks of the RKI are the identification, prevention and control of diseases, especially infectious diseases, as well as the collection of data and the preparation of studies for the development of prevention recommendations in the health care system[24].

IV.6. Considerations and implications

Tuberculosis is still the most common bacterial infectious disease leading to death worldwide. According to estimates of the World Health Organization (WHO), more than 20,000 people contract tuberculosis every day, and 5,000 die from it every day. The main burden of the disease particularly affects Africa, in the regions south of the Sahara, and Asia (including India and China). In Europe, the frequency of tuberculosis is distributed very differently and shows a clear east-west gradient with comparatively high numbers of new cases in the Eastern European countries[21,38].

The new decade will be decisive for the elimination of TB - an infectious disease that is generally easy to treat, but which nevertheless affects about 10 million people worldwide every year and causes about 1.5 million die. In its End TB Strategy, the WHO formulates the goal of reducing the incidence of TB worldwide by 90% and the number of TB deaths by 95% by 2035 compared to 2015[38].

In recent years, however, many important steps have been taken towards TB elimination, thus, new diagnostic tests allow a comparatively simple, fast and reliable diagnosis of TB including testing for rifampicin resistance. To achieve the elimination of TB (defined as < 1 TB case/1 million population), drug resistance is one of the biggest obstacles[37]. The World Health Organization (WHO) estimates that in 2017, 558,000 tuberculosis cases worldwide were caused by bacterial strains who were resistant to rifampicin (RR), the most effective first-line tuberculosis drug. Of these, an estimated 82% had additional resistance to the second most important first-line drug, isoniazid (H), and by definition, multi-resistant tuberculosis (MDR-TB)[36].

In many places, health systems have been strengthened, vulnerable groups identified and access to health care improved. The introduction of several highly effective substances in the treatment of multidrug-resistant TB (MDR-TB) has paved the way for shorter and better tolerated

treatment. Progress is also being made in the preventive area, with the management of latent tuberculous infections (LTBI) of contact persons and other risk groups is recognized as an important part of successful TB control. In addition, several vaccine candidates are in clinical trials.

Essential aspect of successful TB control is the level of knowledge of practitioners and health care personnel, but of course also of those affected with their environment. With the expansion and continuous updating of Internet presence, it provides a very good support for laymen and for qualified personnel and allows quick access to current national recommendations and guidelines.

From the comparison of the protocols several key points can be concluded. Firstly, Spain and Germany have committed themselves to establishing guidelines for TB prevention in order to achieve the goals proposed by WHO at the global level. Both countries agree on case reporting, chemoprophylaxis, and treatment of latent tuberculosis. Also, as shown in the current review, diagnostic methods are comparable in both countries. Both aim to reduce the number of cases and to support patients in case of possible infection. Finally, an individualized assessment and subsequent monitoring must be taken into account to decide on the diagnosis in people in circumstances of risk arising from their socio-economic conditions, in particular those without home and children from countries with a high incidence of TB in adoption or migration processes. In addition, patient education, the constant search for the best treatment methods and a multidisciplinary team are very important for the well-being of patients and their families.

Author Contributions:

Funding: This research received no external funding

Conflicts of Interest: The authors declare no conflict of interest

References

1. Coppeta, L.; Pietroiusti, A.; Neri, A.; Janni, A.; Baldi, S.; Papa, F.; Magrini, A. Prevalence and Risk Factors for Latent Tuberculosis Infection among Healthcare Workers in a Low Incidence Country. *Open Respir Med J* **2019**, *13*, 1–4, doi:10.2174/1874306401913010001.

2. Bonville, C.; Domachowske, J. Tuberculosis. In *Vaccines: A Clinical Overview and Practical Guide*; Domachowske, J., Suryadevara, M., Eds.; Springer International Publishing: Cham, 2021; pp. 363–372 ISBN 978-3-030-58414-6.

3. World Health Organization Universal health coverage, multisectoral action and social determinants. In *Global tuberculosis report 2019*; World Health Organization: Geneva, 2019; pp. 141–163 ISBN 978-92-4-156571-4.

4. European Centre for Disease Prevention and Control Despite 4% decline in EU/EEA TB cases, challenges remain in achieving targets Available online: https://www.ecdc.europa.eu/en/news-events/world-tb-day-2020-time-end-tb (accessed on Dec 1, 2020).

5. World Health Organization Incidence of tuberculosis Available online: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/incidence-of-tuberculosis-(per-100-000-population-per-year) (accessed on Dec 1, 2020).

6. Coppeta, L.; Pietroiusti, A.; Balbi, O.; Baldi, S. QuantiFERON-TB Gold Plus evaluation for latent tuberculosis infection among Italian healthcare workers: a cross-sectional study. **2019**, doi:10.2427/13123.

7. European Centre for Disease Prevention; Control/WHO Regional Office for Europe. *Tuberculosis surveillance and monitoring in Europe 2020 – 2018 data.*; ECDC: Stockholm, 2020; ISBN 978-92-9498-457-9.

8. Eurostat Standardised death rate due to tuberculosis, HIV and hepatitis by type of disease number per 100 000 persons Available online: https://ec.europa.eu/eurostat/databrowser/view/sdg_03_41/default/table?lang=en (accessed on Dec 1, 2020).

9. Dara, M.; Solovic, I.; Sotgiu, G.; D'Ambrosio, L.; Centis, R.; Tran, R.; Goletti, D.; Duarte, R.; Aliberti, S.; de Benedictis, F.M.; et al. Tuberculosis care among refugees arriving in Europe: a ERS/WHO Europe Region survey of current practices. *Eur Respir J* **2016**, *48*, 808–817, doi:10.1183/13993003.00840-2016.

10. *Programmatic management of latent tuberculosis infection in the European Union*; Europäisches Zentrum für die Prävention und die Kontrolle von Krankheiten, Ed.; ECDC scientific advice; ECDC: Stockholm, 2018; ISBN 978-92-9498-266-7.

11. Dobler, C.C.; Luu, Q.; Marks, G.B. What Patient Factors Predict Physicians' Decision Not to Treat Latent Tuberculosis Infection in Tuberculosis Contacts? *PLoS ONE* **2013**, *8*, e76552, doi:10.1371/journal.pone.0076552.

12. Yousefi Avarvand, A.; Khademi, F.; Tafaghodi, M.; Ahmadipour, Z.; Moradi, B.; Meshkat, Z. The roles of latency-associated antigens in tuberculosis vaccines. *Indian Journal of Tuberculosis* **2019**, *66*, 487–491, doi:10.1016/j.ijtb.2019.04.012.

13. Hermes, L.; Kersten, J.F.; Nienhaus, A.; Schablon, A. Risk Analysis of Latent Tuberculosis Infection among Health Workers Compared to Employees in Other Sectors. *IJERPH* **2020**, *17*, 4643, doi:10.3390/ijerph17134643.

14. Peters, C.; Kozak, A.; Nienhaus, A.; Schablon, A. Risk of Occupational Latent Tuberculosis Infection among Health Personnel Measured by Interferon-Gamma Release Assays in Low Incidence Countries—A Systematic Review and Meta-Analysis. *IJERPH* **2020**, *17*, 581, doi:10.3390/ijerph17020581.

15. Bilir, S.; Ghavam, E.; Sancak, L. The Comparison of Occupational Health and Safety Legislation of Different Countries from the View of Inspection.; El Paso, TX, USA, 2014; p. 7.

16. Belingheri, M.; Paladino, M.E.; Riva, M.A. Beyond the assistance: additional exposure situations to COVID-19 for healthcare workers. *J. Hosp. Infect.* **2020**, *105*, 353, doi:10.1016/j.jhin.2020.03.033.

17. *PLAN PARA LA PREVENCION Y CONTROL DE LA TUBERCULOSIS EN ESPAÑA*; Ministerio de Sanidad, Consumo y Bienestar social, Ed.; Ministerio de Sanidad, Consumo y Bienestar social: Madrid,Spain, 2019;

18. *S2k Leitlinie 020-019: Tuberkulose im Erwachsenenalter*; Deutsche Gesellschaft für Pneumologie und Beatmungsmedizin, Ed.; Deutsche Gesellschaft für Pneumologie und Beatmungsmedizin: Germany, 2017; ISBN 978-92-9498-266-7.

19. Tagliani, E.; Anthony, R.; Kohl, T.A.; de Neeling, A.; Nikolayevskyy, V.; Ködmön, C.; Maurer, F.P.; Niemann, S.; van Soolingen, D.; van der Werf, M.J.; et al. Use of a Whole Genome Sequencing-based approach for Mycobacterium tuberculosis surveillance in Europe in 2017–2019: an ECDC pilot study. *Eur Respir J* **2020**, 2002272, doi:10.1183/13993003.02272-2020.

20. Millet, J.-P.; Moreno, A.; Fina, L.; del Baño, L.; Orcau, A.; de Olalla, P.G.; Caylà, J.A. Factors that influence current tuberculosis epidemiology. *European Spine Journal* **2013**, *22*, 539–548, doi:10.1007/s00586-012-2334-8.

21. Dara, M.; Acosta, C.; World Health Organization; Regional Office for Europe *Roadmap to implement the tuberculosis action plan for the WHO European region 2016-2020: towards ending*

tuberculosis and multidrug-resistant tuberculosis; World Health Organization, Regional Office for Europe: Copenhagen, 2017; ISBN 978-92-890-5169-9.

22. European Centre for Disease Prevention and Control Surveillance Atlas of Infectius Diseases Available online: https://atlas.ecdc.europa.eu/public/index.aspx?Dataset=27&HealthTopic=54 (accessed on Dec 1, 2020).

23. Herzmann, C.; Sotgiu, G.; Bellinger, O.; Diel, R.; Gerdes, S.; Goetsch, U.; Heykes-Uden, H.; Schaberg, T.; Lange, C.; For the TB or not TB consortium Risk for latent and active tuberculosis in Germany. *Infection* **2017**, *45*, 283–290, doi:10.1007/s15010-016-0963-2.

24. Brodhun, B.; Altmann, D.; Hauer, B.; Haas, W. *Bericht zur Epidemiologie der Tuberkulose in Deutschland für 2018*; Robert Koch-Institut, Ed.; Robert Koch-Institut.; Berlin, 2019; ISBN 978-3-89606-300-7.

25. Casas, I.; Esteve, M.; Guerola, R.; García-Olivé, I.; Ruiz-Manzano, J. A Study of Tuberculosis Infection in Workers at a University General Hospital: Associated Factors and Evolution in 20 Years. *Archivos de Bronconeumología (English Edition)* **2011**, *47*, 541–546, doi:10.1016/j.arbr.2011.07.005.

26. Schablon, A.; Beckmann, G.; Harling, M.; Diel, R.; Nienhaus, A. Prevalence of latent tuberculosis infection among health care workers in a hospital for pulmonary diseases. *Journal of Occupational Medicine and Toxicology* **2009**, 7.

27. Schablon, A.; Nienhaus, A.; Ringshausen, F.; Preisser, A.; Peters, C. Occupational Screening for Tuberculosis and the Use of a Borderline Zone for Interpretation of the IGRA in German Healthcare Workers. *PloS one* **2014**, *9*, e115322, doi:10.1371/journal.pone.0115322.

28. Suárez, I.; Fünger, S.M.; Kröger, S.; Rademacher, J.; Fätkenheuer, G.; Rybniker, J. The Diagnosis and Treatment of Tuberculosis. *Dtsch Arztebl Int* **2019**, *116*, 729–735, doi:10.3238/arztebl.2019.0729.

29. Parsons, L.M.; Somoskövi, Á.; Gutierrez, C.; Lee, E.; Paramasivan, C.N.; Abimiku, A.; Spector, S.; Roscigno, G.; Nkengasong, J. Laboratory Diagnosis of Tuberculosis in Resource-Poor Countries: Challenges and Opportunities. *Clin. Microbiol. Rev.* **2011**, *24*, 314, doi:10.1128/CMR.00059-10.

30. *Tuberculosis: Clinical Diagnosis and Management of Tuberculosis, and Measures for Its Prevention and Control*; National Institute for Health and Clinical Excellence (UK): London, 2011; ISBN 978-1-84936-537-6.

31. Casas, I.; Latorre, I.; Esteve, M.; Ruiz-Manzano, J.; Rodriguez, D.; Prat, C.; García-Olivé, I.; Lacoma, A.; Ausina, V.; Domínguez, J. Evaluation of Interferon-Gamma Release Assays in the Diagnosis of Recent Tuberculosis Infection in Health Care Workers. *PLOS ONE* **2009**, *4*, e6686, doi:10.1371/journal.pone.0006686.

32. Kang, Y.A.; Lee, H.W.; Yoon, H.I.; Cho, B.; Han, S.K.; Shim, Y.-S.; Yim, J.-J. Discrepancy Between the Tuberculin Skin Test and the Whole-Blood Interferon γ Assay for the Diagnosis of Latent Tuberculosis Infection in an Intermediate Tuberculosis-Burden Country. *JAMA* **2005**, *293*, 2756–2761, doi:10.1001/jama.293.22.2756.

33. Kim, S.J.; Lee, S.-H.; Kim, I.; Kim, H. joong; Kim, S.; Rieder, H. Risk of occupational tuberculosis in National Tuberculosis Programme laboratories in Korea. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease* **2007**, *11*, 138–42.

34. Hermes, L.; Kersten, J.F.; Nienhaus, A.; Schablon, A. Risk Analysis of Latent Tuberculosis Infection among Health Workers Compared to Employees in Other Sectors. *IJERPH* **2020**, *17*, 4643, doi:10.3390/ijerph17134643.

35. Ködmön, C.; Zucs, P.; van der Werf, M.J. Migration-related tuberculosis: epidemiology and characteristics of tuberculosis cases originating outside the European Union and European Economic Area, 2007 to 2013. *Eurosurveillance* 2016, *21*, 30164.

36. van der Werf, M.J.; Sprenger, M. Drug-resistance - a challenge for tuberculosis control in the European Union and European Economic Area. *Eurosurveillance* **2014**, *19*, doi:10.2807/1560-7917.ES2014.19.11.20737.

37. Heyckendorf, J.; van Leth, F.; Avsar, K.; Glattki, G.; Günther, G.; Kalsdorf, B.; Müller, M.; Olaru, I.; Rolling, T.; Salzer, H.; et al. Treatment responses in multidrug-resistant tuberculosis in Germany. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease* **2018**, *22*, 399—406, doi:10.5588/ijtld.17.0741.

38. Sosa, L.; Njie, G.; Lobato, M.; Morris, S.; Buchta, W.; Casey, M.; Goswami, N.; Gruden, M.; Hurst, B.; Khan, A.; et al. Tuberculosis Screening, Testing, and Treatment of U.S. Health Care Personnel: Recommendations from the National Tuberculosis Controllers Association and CDC, 2019. *MMWR Morb Mortal Wkly Rep* **2019**, *68*, 439–443, doi:10.15585/mmwr.mm6819a3external icon.

Chapter V. Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot

Chapter V. Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], María Pilar Martínez-Jiménez [3,4], Manuel Vaquero-Abellán [5,6], María Dolores Redel-Macías [2] and Pilar Aparicio-Martínez [5,6,*]

[1] SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de

[2] Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C.-A.); ig1remam@uco.es (M.D.R.-M.)

[3] Applied Physics, Radiology and Physics Medicine Department, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, 14014 Cordoba, Spain; fa1majip@uco.es

[4] Simulation Models in Energy, Transport, Physics, Engineering, Occupational Hazard Researcher Group, Junta de Andalucía, and Dpt. Applied Physics, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, 14014 Cordoba, Spain

[5] GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; en1vaabm@uco.es

[6] Departamento de Enfermería, Fisioterapia y Farmacología, Campus de Menéndez Pidal, Universidad de Córdoba, 14014 Córdoba, Spain

Abstract: Most of blood borne and airborne pathogens are highly contagious, harmful and have prevalence among healthcare workers. In this group, healthcare students, especially nursing undergraduates, have even higher risk to be exposed and suffered a contagious accident. One of the main pillars to prevent exposure to such pathogens and decrease accidents seems to be through education. A prospective observational educational research focused on quantifying the students' knowledge, and prevention culture was carried out. The educational approach based on the development of a technological tool, its integration in the students' education, and posterior assessment. The Chi-square, ANOVA, Kruskal–Wallis, Man–Whitney U, and Spearman correlations were used to determine the effect of such educational methodology. The results, previous to the integration of the educational approach, showed differences between the elementary and proficient knowledge and correct procedure in each academic year ($p < 0.05$), being the best year the third academic year. The mean of elementary knowledge among second year students after the inclusion of the educational methodology improved for 2017/2018 with a mean of 7.5 (1.11) and in 2018/2019 with 7.87 (1.34). This study argued that the educational approach proposed could improve the prevention culture and knowledge among students and future healthcare professionals.

Keywords: prevention culture; continuous training; web platform; nursing students

V.1. Introduction

Since the first time that biological exposure to blood was studied by Ramazzini [1], more pathogens have been described as hazardous, being up to 44% of them viral [2]. Most of the current harmful microorganisms are blood borne, such as human immunodeficiency virus (H.I.V.), and airborne pathogens, such as tuberculosis, being highly presented in the daily day of healthcare workers [3,4]. These workers are at risk of being exposed to diverse pathogens, from mortal (i.e., Ebola) to highly contagious viruses (i.e., Sars-covid-19) via material or surfaces and corporal fluids[5,6].

This threat among healthcare workers continues to be presented and has economical and health repercussions in the healthcare systems and the workers' physical and mental health [5,6]. In order to decrease this hazard, several educational programs have been created and implemented to raise awareness among healthcare workers regarding risk and prevention, including hand washing or disposal in specific resistant containers [7]. At the same time, organizations and political structures, such as National Health System in England [5], have created prevention policies and updated guidelines to decrease the jeopardy of exposure among healthcare workers, protect their health, and concise these workers [8–10].

Among the measures taken by the organizations, the education (initial or continuous training) of their healthcare worker has been of the main pillars to prevent biological exposure and accidents [11]. Despite the modifications and inclusion of initial and continuous training carried out during more than two decades, the level of knowledge and compliance with universal precautions procedures continues to be limited [12,13]. This difficulty in achieving optimum levels of knowledge seems to be linked to the reduced safety culture [14]. The safety culture, which can be defined as values shared among workers regarding what is considered necessary among the healthcare workers, has been defined as a key point for occupational and health measures in different working areas [14]. One stage of the workers' life that the learning process is more dynamic and adapting to changes is in the university years [8].

As future young workers, healthcare students are more drive to engage themselves in risky situations that they are not prepared to face, based on their willingness to take on challenges and more responsibilities. Moreover, the students rarely received information regarding the rate of the biological accidents that they had suffered during the practice [15]. Among the undergraduate healthcare students, the nursing students have a higher risk of exposure to pathogens because of their direct contact with the patients, lack of knowledge and safety culture, and more willingness to take risks [16]. Furthermore, data about biological accidents among nurses' students continues to reduce, except from previous studies carried out in other countries, such as Italy [17,18] or

China [19]. Moreover, only a few researchers have recently studied the incidence of biological accidents, knowledge and safety culture among nursing students in Spain [20].

V.2. Background

The evaluation of knowledge among healthcare students has been considered an upholder at improving their education and their safety culture, resulting in compromising the occupational health and security measures taken by the students [21]. The development of new educational methodologies [22] to improve the training and knowledge about preventing an accident and protocols post-exposition are a main key to improve the students safety culture. Simultaneously, educational institutions and researchers have created models and new methodological approaches based on computers and other information and communication technologies (I.C.T.s) to be integrated in the classroom [12]. These new methodologies search to adapt and develop platforms or applications via gamification or interactive environments, such as virtual reality, according to the organizations, students or professors' needs [23,24]. All these tools are integrated into a platform or used individually, allowing ubiquitous, electronic or blended learning [25]. Previous works have accomplished several functional software applications available for mobile devices focused on nursing students [24,26].

Therefore, new teaching methodologies, based on ICTs and focused on improving the training and information about biological accidents and prevention, holds a great importance for nursing students [27]. These technologies were created to develop tutorials, games, virtual laboratories, videos, simulations, and virtual reality [24,27]. These technological and educational tools developed in computer-based training have four pillars to achieve their intended goal (feedback, appealing experience, creative design, and assessment of designed program) [28]. These pillars seem to positively improve the knowledge and training educational approaches via applications [28].

Nevertheless, current platforms, focused on risk prevention and occupational training and for undergraduate nursing students, continues to be lacking, which could make more difficult to improve their safety culture. Despite the incidence, low rate of prevention measures compliance, and safety culture [29], the current nursing students seemed not to be a priority, being included in the articles more as secondary actors [17]. Nevertheless, the education, aptitude, and knowledge of the undergraduate nursing student will define them as healthcare workers, and the future of the safety culture in this specific group [30].

Based on the previous statements, the current study had as main objective to determine the efficacy of the platform created, as a training tool, to improve the knowledge and safety culture among nursing students. In addition, the other secondary objectives were to analyze the state

previous to the inclusion of the training tool, which was framed in an educational methodology, and the students' opinion.

V.3. Materials and Methods

The current study presents a prospective observational educational research focused on quantifying the students' knowledge and prevention culture after introducing the educational approach based on a blended learning. In addition, cross-sectional studies were carried out to determine the students' knowledge and occupational culture's consecutive measures and posterior knowledge and opinion after including the platform.

V.3.1. Educational Approach

V.3.1.1. Creation of the Platform

The platform (https://www.uco.es/investiga/grupos/LVRiesgosLaborales/formacion-sanitaria/) has been created using CakePHP as the primary programming language, and for the architecture pattern, it uses the control view model. Other languages, such as HTML5, CSS3, JavaScript with jQuery, JSON, and Ajax, were used. The design diagram mainly divided the coding into three layers: the model, view, and controller. This structure allows useful, resourceful, adaptable, and friendly software following the principle of "at any place and at any time". This platform was divided into different sections depending on the user, administrator, and system programmer. This web was structured into tutorials, e-games, image galleries, valuation surveys, virtual laboratories, and help. The tutorials include a title, short description, and an image. The e-games was created mainly by using HtmL5, resulting in a more playful, visual, and short data training. An example of the games (Figure 1) focused on finding airborne and blood borne pathogens, visually appealing and more effective. The image galleries show a title, short description, and links to other webpages or further information. The valuation surveys were based on the Kahoot program. This survey was used during the training and information sessions in the theoretical subjects and clinical practice before the actual practice. Finally, the virtual laboratory focused on creating an interactive environment being accessible at any time. Moreover, a connection to social networks, such as Facebook and Twitter, were included. These sections were developed to integrate the primary information, images, and straightforward explanations that the student would need.

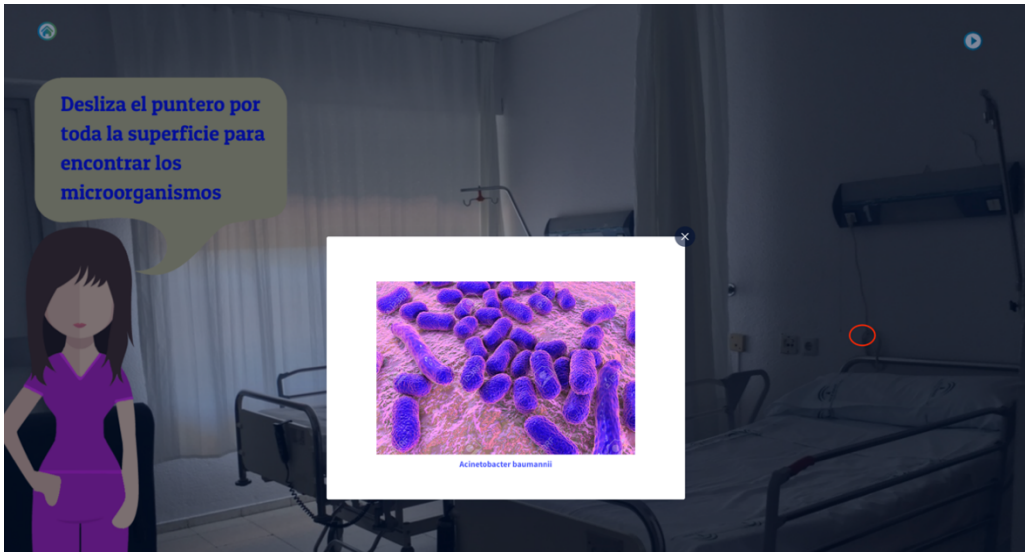


Figure 10. Example of a game in which the students need to locate the pathogens' situation around the working environment. Note: the circle colored in red is the light cable where the pathogen is placed

The platform creation was based on the fourth pillars (Figure 2) relating to gamification as an effective method for adapting and evaluating this platform as a prevention learning tool. This e-learning system's design focused on stimulating knowledge acquisition and sought to apply a more dynamic teaching process being modified according to create a more appealing experience for the user.

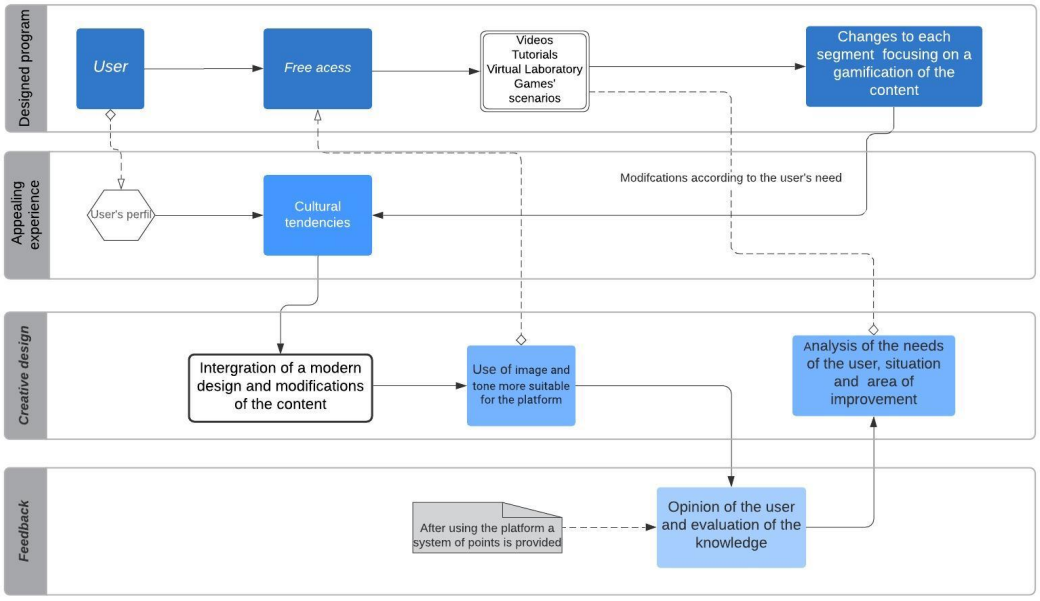


Figure 11. Flowchart of the integration of the fourth pillars in the structure of the educational methodology

Additionally, the platform's design allowed several modifications to its content and the user's needs. An example of this is the virtual laboratory last modified in May 2020 to provide a

more complex intravenous puncture situation since the students could not access patients (Figure 3).

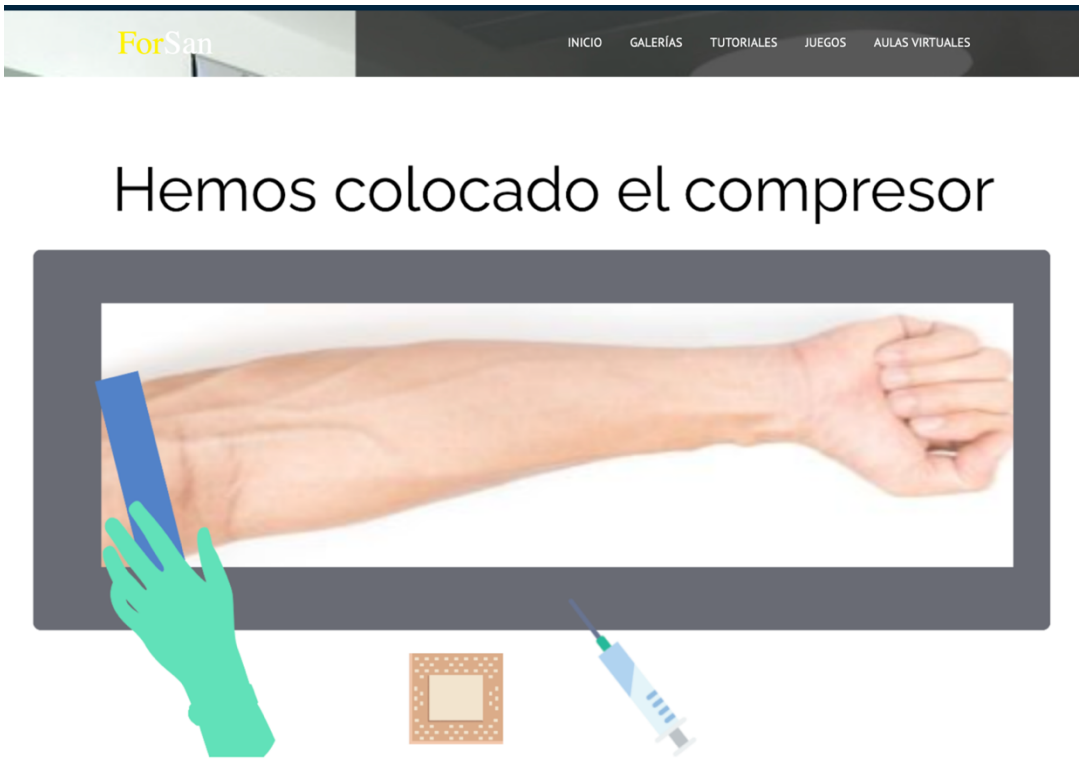


Figure 12. Virtual laboratory with the last modification following the impossibility to access patients

V.3.1.2. Educational Paradigm and Procedure

The educational paradigm was based on combining in the classroom of face-to-face learning experiences with the platform created as an online learning experience, which can be defined as blended learning [31]. This educational paradigm focused on a quantitative or empiric approach, including the immediate results and the students' opinion, eliminating the qualitative approach [32], following the theoretical models of blended learning [31]. This approach was selected to achieve the theoretical framework of the blended learning paradigm, focusing on exploring the state of the safety culture previous the use of the platform and possible associations [31]. The evaluation method was the context, input, process, and product (C.I.P.P.) method [33], by which five specialists in the prevention of occupational risk and engineering determine the area of improvement. These improvements focused on coding and structure being used in the platform.

For the students' acquirement of knowledge and skills, the teachers were presented in the classroom when it was presential to explain and use the platform, creating an assisted blended learning. However, the platform's versatility allows modification of the learning process from blended to virtual learning, as it happened with the pandemic and posterior lockdown [34]. Additionally, the students could access freely and have feedback with the teacher via the Moodle

platform. This is why, for this educational process to be successful, the teachers provided help and support in acquiring prevention knowledge through communication and obtaining feedback on the students' progress and their way of working. Finally, the students carried out a test to evaluate their knowledge after using the educational platform. The teaching and training were carried out during the first and second semesters. After the clinical practices, the students responded to an interactive survey in which the students' knowledge about prevention was measured. The only exception was in the second semester of the course 2019/2020, in which the clinical practices were paused.

V.3.2. Determination of the Students' Knowledge

V.3.2.1. Data Collection

Before completing the platform, a sample of nursing students from different academic years was recruited, who voluntarily accessed the survey online during May and June in 2016. This recruitment sought to determine each academic year's level of knowledge and possible lack of safety culture. The survey was distributed after ethical approval from the Ethics Committee of the University in 2015 (Reference 428). The survey, distributed at the end of the clinical practice in the second semester, included the description, objective, and the consent to participate that student signed. The nursing students received several theoretical practices and simulations before the clinical practices started. These students' information and training focused on prevention measures, protocols, seroconversion incidence, and post-exposure procedures. It is important to note that the European credit for a nursing degree corresponds to 20 h/credit. Each academic year was formed by 120 students (110–130), although the students from the first year were excluded from the study. The nursing students were from the second, third, and fourth academic year, that belonged to the Medicine and Nursing School and had already been in hospital practices

The platform's assessment, focusing on design and appeal, was carried out from March to April 2017. These students chosen for the evaluation of the structure were from the second year, that did not receive the prevention training with the platform, and they evaluated the initial platform by pointing out improvements and possible changes that could be implemented. The posterior analysis received the approval of the updated protocol from the reference Ethics Committee in 2019 (Number 288, Reference 4258). The educational approach's estimation based on a survey of students' knowledge, being carried in the following years up to 2020 (May 2020), evaluated a total of 267 students for the three years. Finally, the students notified whether they did or did not suffer a biological accident, except for the course 2019/2020, the students did not

have an accident because of the lack of clinical practices. The difference between having a higher level of knowledge and not experiencing a biological accident was studied. The results were compared to the knowledge and incidence of biological accidents from students between courses (2016/2017, 2017/2018, 2019/2018, and 2019/2020).

V.3.2.2. Instruments

Before the inclusion of the educational technology, a survey that combined the questionnaires created by Merino-de la Hoz et al. in 2010 and Orozco in 2013 was used to measures the students' knowledge [35,36]. The survey was composed of 48 questions, based on 38 closed answer items and ten open answers. The ten available answer questions were focused on the type of biological accident, year of the accident, experience, and post-exposure measures taken. The response was one per student, without the option to retake the survey. The sample's descriptive data were age, gender, academic year, undergraduate background, and working experience. The survey was segmented into three main blocks. The first block focused on knowledge regarding prevention actions and biological agents. In addition, this block is divided into two sections: elementary and proficient knowledge. The elementary knowledge was based on universal prevention measures such as hand washing or personal protection equipment. Differently, proficient knowledge focused on specific data regarding prevention, occupational safety, and risks, such as seroconversion or treatments. The second block focused on the correct procedures during the practices, such as following the isolation protocols or changing gloves. Finally, the final block centred on the incidence of biological accidents, the factors contributing to the accident, and the measures taken after the incident (Table 1).

Table 1. Structure of the survey used on the students.

Blocks	Description	Questions	Examples
Prevention of Knowledge	Elementary Knowledge	Ten questions about elementary prevention measures	Select the prevent universal actions
	Proficient Knowledge	Ten questions about specific information	Human inmunodeficiency virus I.V. seroconversion rate

Correct Procedures	Procedures during the practices	Eight questions about preventing universal measures and avoiding incorrect procedures	How often do you re-encapsulated needles?
Biological accident	Having or not a biological accident and procedure post-exposure	Ten questions about the biological accident and procedure post-exposure	What type of biological accident did you have?

The platform's assessment was accomplished by filling an in-person survey and included their personal opinion about the platform, being carried out from March to April 2017. This survey was based on a five-point scale, from one (minimum) to five (maximum) and according to the work of Garret Jackson in 2006 and Lahti M et al., 2014 [37,38]. The survey was segmentized into three segments, the education received previously (effectiveness of this education received previously (E1), the efficacy of the training to prevent biological accidents (E2) and frequency of using such training (E3)), valuation of the platform (easy use of the platform (V1), the utility of the gallery (V2), the usefulness of the tutorials (V3), usability and practicality of the virtual laboratories and games (V4) and use of social networks in which were included news and updated information (V5)) and finally their opinion of the platform as an interactive training (games and practice methodologies (O1), tutorials and practice information (O2), virtual simulations (O3), graphics and visual tools (O4) and interactive learning methodologies such as the platform developed (O5)). Two additional questions were included. The first focused on the students' satisfaction concerning education, and the second was based on the students' opinions about including games or other methodologies for occupational safety education.

The survey to determine the knowledge of the students' posterior to the use of the platform was based on the survey by Merino-de la Hoz et al. and Orozco [35,36], focusing on the ten questions regarding the elementary knowledge. These surveys were adapted using "Kahoot!" an interactive software to fill in the survey or Moodle platform, obtaining a sample of approximately 110 students per academic year, except for 2020, that only 48 students filled it.

The programs used were Excel version 2017 (Microsoft Corporation, Redmond, WA, USA) and S.P.S.S. program version 25 (IBM SPSS Statistics, Armonk, NY, USA) for the statistical analysis. All the data was saved in a cloud available only to the researches. For the sample calculation, the E.P.I.D.A.T. version. 4.2. (Servicio de Epidemioloxía de la Dirección Xeral de Saúde Pública del Servicio Galego de Saúde (S.E.R.G.A.S.), Galicia, Spain) was used. The number of students was determined from an expected proportion of 30%, a 9% precision, and a confidence

level of 95%. The initial predicted size was 100 students, though the actual size obtained was lower. The sample size for the validation of the students' opinions was calculated from a standard deviation of 1.5, a 5% precision, and a confidence level of 95%.

V.3.2.3. Statistical Analysis

The data were analyzed, and the normalization was studied using the Shapiro–Wilk test for the data before the inclusion of the educational approach. This analysis showed that the variable elementary knowledge was normalized, though the remaining variables were not standardized. The correct procedures variable was transformed into a quantitative variable based on a scale of 10, and a global variable focused on global preventive knowledge was created using the score obtained from the elementary and proficient preventive knowledge. The descriptive and frequencies were studied individually for each year, and the chi-test was used for assessment of the qualitative variables, i.e., the incidence of biological accidents and academic year. The student t-test was applied to knowledge, ANOVA test of variance for the academic years, and Kruskal–Wallis, Man–Whitney U, and Spearman correlations were used for comparisons.

The analysis of the comparison of each course (2016/2017, 2017/2018, 2019/2018, and 2019/2020) focused on frequencies and chi-square to determine the difference between each course, elementary knowledge of the students, and incidence of biological accidents. Additionally, for the courses, after the inclusion of the platform, being 2017/2018, 2019/2018, and 2019/2020, each correct answer was measured via scores, resulting in a mean of correct answers and standard deviation.

V.4. Results

The initial analysis of the data from the 2016/2017 course showed that only 22.6% of the population carry out the survey, representing 80 students out of the 354 sent the survey. This analysis also showed that 81.3% were women aged between 22 and 23, with an undergraduate background in health (45%), i.e., laboratory technicians, and 11.3% of the sample was working. The students were 27.5% from the second year, 43.9% from the third year, and 28.7% from the fourth year—87.5% from Spain, 10% from Portugal, and 2.5% from Eastern countries, i.e., Poland. Furthermore, 13 students suffered a biological accident, although the remaining data about such an accident was obtained for 12 students.

The correct response frequency between the elementary and proficient knowledge and correct procedure in each academic year was different (Table 2). The data showed a low level of correct answers according to knowledge and proper occupational safety and health measures among students, independently to the academic year. The 3rd presented had a higher answered

prevention knowledge and occupational safety and health (O.S.H.) measure than the second and fourth academic years. The students from the third had tighter confidence intervals compared to the second and fourth year, with the lower interval set on four. The students' global knowledge was sufficiently obtaining the maximum in the third, with tighter intervals compared to the second and fourth academic year (Table 2). In addition, the higher value of O.S.H. measures was obtained in the third year with a 0.8 difference between the intervals. Furthermore, the maximum values for elementary and proficient knowledge were obtained in the third year (maximum = 10; maximum = 6), followed by the second year for the elementary knowledge (maximum in elementary knowledge = 9; maximum in proficient knowledge = 4) and the fourth-year or proficient knowledge (maximum in elementary knowledge = 8; maximum in proficient knowledge = 5).

Table 2. Descriptive analysis of each year of the 80 students.

Academic Year	Number of Students	Elementary Knowledge		Proficient Knowledge		Occupational Safety and HealthMeasures		Global Prevention Knowledge	
		Mean (S.D.)	CI 95%	Mean (S.D.)	CI 95%	Mean (S.D.)	CI 95%	Mean (S.D.)	CI 95%
Second Year	22	7.3 (1.0)	6.8–7.8	2.9 (0.8)	2.5–3.3	6.6 (1.3)	6.0–7.2	5.1 (0.7)	4.8–5.4
Third Year	35	7.4 (1.2)	7–7.8	3.6 (1)	3.2–3.9	7.3 (1.2)	6.9–7.7	5.5 (0.8)	5.3–5.5
Fourth Year	23	6.3 (0.9)	5.8–6.7	3.7 (1)	3.1–4.1	5.0 (0.8)	4.6–5.3	5.0 (0.8)	4.6–5.3

The relationship between the elementary and proficient knowledge and correctly carrying out the O.S.H. procedures was analyzed regarding the students' academic year (Table 3). All variables' data were studied between groups, showing a significant difference between elementary and proficient knowledge ($p < 0.05$). The results showed a difference between groups (second, third and fourth academic year) and the elementary and proficient knowledge, although, for the correct procedure, no significant difference was found among the groups ($p > 0.05$). The outcomes of this examination showed higher levels of correct answers regarding proficient knowledge in the third year compared with the second academic year ($p < 0.05$). This result was similar when compared second and fourth for the proficient and elementary knowledge, showing higher correct answers in the students from the fourth to the second academic year ($p < 0.01$). The comparative between the third and fourth showed no significant differences for the proficient

knowledge ($p > 0.05$) and, in contrast, higher differences for the elementary knowledge ($p < 0.01$). Although the correct O.S.H. measures were not linked to a higher probability of suffering a biological accident, the O.S.H. was associated with higher notions of elementary knowledge ($p < 0.05$).

Table 3. Relationship between knowledge and correct procedure according to each academic year.

Blocks	3rd Academic Year	2nd and 3rd	2nd and 4th	3rd and 4th
Elementary Knowledge	<0.01	>0.05	<0.01	<0.001
Proficient Knowledge	<0.01	<0.01	<0.05	>0.05
Correct Procedure	>0.05	>0.05	>0.05	>0.05

The frequencies presented 9.1% of second-year students, 14.3% third year, and 26.1% fourth had a hazardous accident with exposure to an airborne or bloodborne pathogen. Nevertheless, most of the students experienced this accident in their second (38.5%) or fourth academic year (38.5%), being less common to have it in third year (15.4%). The correlations showed a significance relationship between having a biological and, accident elementary (Spearman's = −0.29; $p < 0.01$) and proficient (Spearman's = 0.27; $p < 0.05$), and correct procedures (Spearman's = −0.23; $p < 0.05$). Nevertheless, the mean of correct response comparing safety culture (knowledge and correct procedure) was insignificant for suffering (mean = 5.2) or not a biological accident (5.6) ($p > 0.05$). Another analysis focused on being a graduated health technician, and a lower probability of a biological accident was carried out, showing significant differences between being a graduated and not suffering biological accident (chi-square = 7.13 and $p < 0.05$).

Out of the students that indicated an incident (16.3%), only 92% included the type of accident, zone, cause, notification, and medical follow-up. The type of biological accident (N = 12) and the reason for the accident were studied. The most frequent accident was needlesticks (41.7%), followed by sharp injuries (33.3%), blood exposure (16.7%), and cuts (8.3%). The zone more common was fingers (83.3%), followed by arms (8.3%) and face (8.3%), and the most frequent cause was lack of knowledge or practice (41.7%), followed by rush (33.3%), inadequate use or knowledge regarding prevention instruments (16.7%) and carelessness (8.3%). The results showed that the most common cause in the second year was a lack of knowledge regarding the procedures (2/4). Meanwhile, the cause more common in the third year was the lack of knowledge regarding the specific procedures (2/3). Finally, in the fourth year, the reason for the accidents was the accident occurred.

Besides, the analysis of the platform carried out in 2017 (N = 40 students from the second academic year) showed a positive opinion regarding the prevention education received (3.1/5), the platform created as an interactive prevention intervention (3.9/5), and the students' opinion about this technological tool for training (3.8/5). These students ranged from 19 to 20 years old (medium = 20 years old), analyzing the platform previous their first clinical practice in the hospital. Out of the 40 students, 36 were women with previous healthcare professional training (11.1%). The most common described was "adequate and helpful" (68%). Each variable of the students' assessments regarding the platform was studied, showing the lowest value the previous training regarding O.S.H. measures and prevention (E3) (Figure 4). Figure 4 showed how social media (V5) had a higher positive evaluation (4.15). The next higher evaluation was the virtual laboratories and games (V4) (4.05), described as highly usable and appealing. Out of the 120 students asked about the platform, and the O.S.H. training, only 17% indication an acceptable grade of satisfaction with the O.S.H. education received. The students' responses about the interactivity and possible use of the platform learning methodologies obtained the maximum ratings (5/5). Almost all of the students (97.2%) indicated their preference for including this technology, mainly through games, by which the platform's content was modified.

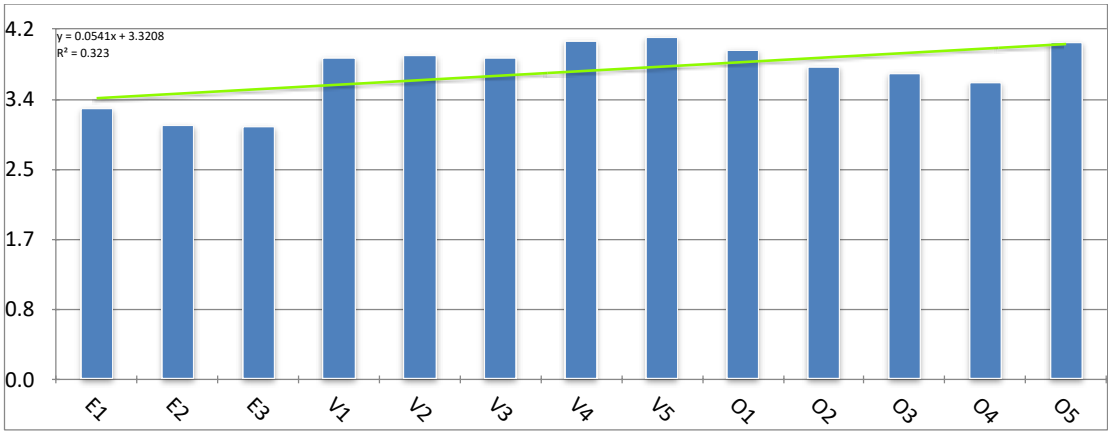


Figure 13. Assessment of the platform created based on the students' opinions

Finally, the comparative analysis between the results of the survey for students on the second academic year in the course 2017/2018 (N = 111) and 2018/2019 (N = 110) showed significant differences in elementary knowledge ($p < 0.01$) and biological accidents ($p < 0.05$) when compared to the course 2016/2017. The means of correct answers regarding the elementary knowledge suffered an increase of a minimum of 0.2 points, although the standard deviation increased. In this sense, in 2017/2018, the mean was 7.5 (1.11) and in 2018/2019 was the best with 7.87 (1.34). The frequency of correct answers for the survey was higher in 2018/2019 (70.3%) than in 2017/2018 (65.2%). The elementary preventive knowledge was also analyzed for 2019/2020 (N

= 60), showing a mean of correct answers of 7.32 (1.04), being almost equal to the course 2016/2019($p > 0.05$). In biological accidents, the frequency of students who suffered a biological accident in the second academic year decreased by up to 1.9%.

V.5. Discussion

The results seemed to reflect on how the educational paradigm improved the student's learning and possibly improved the prevention culture's base. The most prominent finding to emerge from the analysis is that these technologies seemed to be useful as a complementary prevention tool for improving knowledge and decreasing biological accidents. This result matches the results from Bejan et al. [39] that indicated how the I.C.T.s improve the acquisition of safety-related knowledge among students even after a year of receiving training with I.C.T.s. Despite the initial results, an outstanding outcoming was that using only a virtual methodology without the student in the classroom seemed to be less effective than using the classroom technology with the students. These results matched the results from Kintu et al. in 2017, that concluded how the combination of technical quality, online tools, and face-to-face support increase the results and even satisfaction [40].

The results of safety culture, knowledge, and correct procedures showed medium and even low levels. The analyses showed that higher levels of knowledge and frequency of correctly performing the procedures during the clinical practices were linked to lower biological accidents. These results seem to match the findings of Wang et al. that proved how, with previous training, students had more prevention knowledge and had better occupational safety [41]. Moreover, these results are similar to be studies that highlighted the insufficient knowledge that healthcare workers have regarding O.S.H. measures and safety culture [15].

The O.S.H. measures did not improve with the academic years' pass, rather the opposite, which could be explained as an integration of the ideas from the healthcare workers' safety culture, whose actions or procedures are based on technical repetition and less guided by protocols or prevention measures [42,43]. During the clinical practices, riskier behaviors were linked to the exposure to airborne and blood pathogen, which was concerned with previous studies that linked risky behaviors and a higher probability of needlesticks and sharp injuries [18,19].

Another important finding was that elementary and proficient knowledge was related to suffering exposure to a pathogen. The result presented a positive correlation between proficient knowledge and biological accidents, indicating how students with higher knowledge regarding prevention or occupational safety suffered from more probability of biological accidents. These results are similar to those based on nurses working in hospitals that indicated a technical and

more in-depth understanding of the prevention measures but suffered accidents [44]. These results may be related more to safety culture since the knowledge is presented, but the actions or significance given to the knowledge continues to be dismissed [14]. Other impressive results were the frequency of biological accidents that was lower than other studies, like Zhang et al., that indicated up to 60.3% of nursing students suffered a needle stick or sharps injuries [19]. A European study recently indicated up to 14.8% of biological accidents among healthcare students and residents [17]. This variation of frequency of biological accidents might be related to the students' range or the previous training, which could explain the similarities between the Italian and the current study. Based on these results, the safety culture and occupational safety and health measures could be limited among students, although protocols or new methodologies have been created [45].

The platform created was evaluated as a competent preventive tool, although the most exciting finding was that the platform's features with better valuation were the sections based on feedback and gamification. These results seem to match previous publications that stated the positive outcomes and valuation of such technologies, especially games as simulations to real scenarios and improving the O.S.H. measures among workers [46].

An explicit limitation of this study is that the sample of students who incorporated the surveys showed little interest from the students regarding improving preventive measures. This manuscript presents a pilot study that may result in a more in-depth analysis of biological accidents and related factors. In addition, another limitation was that the platform is only available in Spanish. Moreover, another source of uncertainty regarding the findings is the possibility of being transferred prevention knowledge to second-year students. These findings may be somewhat limited by the method of analysis and recruitment of the data. Finally, another limitation of the study was the time skipped between obtaining the biological data and current importance.

Further research would explore the inclusion of simulations via role play and virtual reality, described as highly significant (end-life, serious games), as interactive training combined with the technology created and technical information.

V.6. Conclusions

This paper has argued that new teaching methodologies based on I.C.T.s as a blended model could improve the prevention culture and knowledge among students and future healthcare professionals.

In addition, based on the study previous to the inclusion of the educational paradigm, it has been discussed how the exposure to airborne and bloodborne pathogens might be related to

students' knowledge and carry out correctly the O.S.H. measures. This study has identified that the ideal year to adequate and highlight the O.S.H. measures would in the beginning of the half of the degree, achieving the best results in the third academic year. This result was a key point, since the educational methodology was decided to take place in the second year to provide adequate knowledge since the early stages of the learning process of the nursing students. In general, the results have discussed how the elementary preventive knowledge and correct O.S.H. measures during the clinical practice procedures might be protective factors against exposures to pathogens. These data supposed a strong base for improving the students' knowledge and O.S.H. measures via the platform and using preferable a blended method.

After in the inclusion of the platform, its assessment showed that students' opinions regarding the inclusion of this educational approach based on technology was satisfactory. The posterior analyses of the elementary knowledge and incidence of biological accidents demonstrated the platform's potential as a useful and practical preventive tool for the nursing students, but healthcare workers could also use it for their continues training. The findings of this platform's probable effectiveness in the decrease of the exposures may contribute in several ways to the prevention of occupational accidents. Additionally, the findings provide further information regarding new interactive learning methodologies and provide a basis for future investigation, based on further gamification, virtual reality, and artificial intelligence.

Author Contributions: Conceptualization, A.C.-A. and M.V.-A.; methodology, E.V.-A. and P.A.-M.; validation E.V.-A. and M.P.M.-J.; formal analysis, E.V.-A., M.P.M.-J. and P.A.-M.; investigation, E.V.-A., M.V.-A. and P.A.-M.; resources, E.V.-A. and M.P.M-J.; data curation, P.A.-M. and E.V.-A.; writing—original draft preparation, M.V.-A., P.A.-M. and E.V-A.; writing—review and editing, M.P.M.-J. and A.C.-A.; supervision, M.D.R.-M. And P.A.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We would like to thank Manuel Zamorano and María José Hernández for the help and support during the platform's Creation.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Franco, G. Revisiting the past strengthens the present: Bernardino Ramazzini and the new occupational health. *Public Health* **2020**, *181*, 180–181, doi:10.1016/j.puhe.2019.12.016.
2. Lindahl, J.F.; Grace, D. The consequences of human actions on risks for infectious diseases: A review. *Infect. Ecol. Epidemiol.* **2015**, *5*, 30048–30048, doi:10.3402/iee.v5.30048.

3. Peng, S.; Chen, Q.; Liu, E. The role of computational fluid dynamics tools on investigation of pathogen transmission: Prevention and control. *Sci Total Environ.* **2020**, *746*, 142090, doi:10.1016/j.scitotenv.2020.142090.
4. Sosa, L.; Njie, G.; Lobato, M.; Morris, S.; Buchta, W.; Casey, M.; Goswami, N.; Gruden, M.; Hurst, B.; Khan, A.; et al. Tuberculosis Screening, Testing, and Treatment of U.S. Health Care Personnel: Recommendations from the National Tuberculosis Controllers Association and CDC, 2019. *MMWR Morb. Mortal. Wkly. Rep.* **2019**, *68*, 439–443, doi:10.15585/mmwr.mm6819a3external icon.
5. Loveday, H.P.; Wilson, J.A.; Pratt, R.J.; Golsorkhi, M.; Tingle, A.; Bak, A.; Browne, J.; Prieto, J.; Wilcox, M. epic3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England. *J. Hosp. Infect.* **2014**, *86*, S1–S70, doi:10.1016/S0195-6701(13)60012-2.
6. Blanco-Mavillard, I.; Parra-García, G.; Fernández-Fernández, I.; Rodríguez-Calero, M.Á.; Personat-Labrador, C.; Castro-Sánchez, E. Care of peripheral intravenous catheters in three hospitals in Spain: Mapping clinical outcomes and implementation of clinical practice guidelines. *PLoS ONE* **2020**, *15*, e0240086, doi:10.1371/journal.pone.0240086.
7. Deuffic-Burban, S.; Delarocque-Astagneau, E.; Abiteboul, D.; Bouvet, E.; Yazdanpanah, Y. Blood-borne viruses in health care workers: Prevention and management. *J. Clin. Virol.* **2011**, *52*, 4–10, doi:10.1016/j.jcv.2011.05.016.
8. Verra, S.E.; Benzerga, A.; Jiao, B.; Ruggeri, K. Health Promotion at Work: A Comparison of Policy and Practice Across Europe. *Saf. Health Work* **2019**, *10*, 21–29, doi:10.1016/j.shaw.2018.07.003.
9. World Health Organization Keep Health Workers Safe to Keep Patients Safe: WHO. Available online: https://www.who.int/news/item/17-09-2020-keep-health-workers-safe-to-keep-patients-safe-who (accessed on 2 November 2020).
10. O'Keeffe, V.; Boyd, C.; Phillips, C.; Oppert, M. Creating safety in care: Student nurses' perspectives. *Appl. Ergon.* **2021**, *90*, 103248, doi:10.1016/j.apergo.2020.103248.
11. Desta, M.; Ayenew, T.; Sitotaw, N.; Tegegne, N.; Dires, M.; Getie, M. Knowledge, practice and associated factors of infection prevention among healthcare workers in Debre Markos referral hospital, Northwest Ethiopia. *BMC Health Serv. Res.* **2018**, *18*, 465, doi:10.1186/s12913-018-3277-5.
12. Gao, Y.; Gonzalez, V.A.; Yiu, T.W. The effectiveness of traditional tools and computer-aided technologies for health and safety training in the construction sector: A systematic review. *Comput. Educ.* **2019**, *138*, 101–115, doi:10.1016/j.compedu.2019.05.003.
13. Sopjani, I.; Jahn, P.; Behrens, J. Training as an Effective Tool to Increase the Knowledge About Hand Hygiene Actions. An Evaluation Study of Training Effectiveness in Kosovo. *Med. Arch.* **2017**, *71*, 16–19, doi:10.5455/medarh.2017.71.16-19.
14. Kim, Y.; Park, J.; Park, M. Creating a Culture of Prevention in Occupational Safety and Health Practice. *Saf. Health Work* **2016**, *7*, 89–96, doi:10.1016/j.shaw.2016.02.002.
15. Tureková, I.; Bagalová, T. Knowledge and Experiences of Safety and Health Occupation Risks among Students. *Int. J. Eng. Ped.* **2018**, *8*, 108, doi:10.3991/ijep.v8i5.8981.

16. Huang, H.; Yi, Q.; Tang, S.; An, R. Occupational exposure among Chinese nursing students: Current status, risking factors and preventive interventions. *Int. J. Clin. Exp. Med.* **2016**, *9*, 16578–16586.
17. Papadopoli, R.; Bianco, A.; Pepe, D.; Pileggi, C.; Pavia, M. Sharps and needle-stick injuries among medical residents and healthcare professional students: Pattern and reporting in Italy-a cross-sectional analytical study. *Occup. Environ. Med.* **2019**, *76*, 739–745, doi:10.1136/oemed-2019-105873.
18. Veronesi, L.; Giudice, L.; Agodi, A.; Arrigoni, C.; Baldovin, T.; Barchitta, M.; Benedetti, T.; Caggiano, G.; Cannizzaro, S.G.; De Giglio, O.; et al. A multicentre study on epidemiology and prevention of needle stick injuries among students of nursing schools. *Ann. Ig.* **2018**, *30*, 99–110, doi:10.7416/ai.2018.2254.
19. Zhang, X.; Chen, Y.; Li, Y.; Hu, J.; Zhang, C.; Li, Z.; Stallones, L.; Xiang, H. Needlestick and Sharps Injuries Among Nursing Students in Nanjing, China. *Workplace Health Saf.* **2017**, *66*, 276–284, doi:10.1177/2165079917732799.
20. García-Gámez, M.; Morales-Asencio, J.M.; García-Mayor, S.; Kaknani-Uttumchandani, S.; Martí-García, C.; Lopez-Leiva, I.; León-Campos, Á.; Fernandez-Ordoñez, E.; García-Guerrero, A.; Iglesias-Parra, R. Adverse events encountered during clinical placements by undergraduate nursing students in Spain. *Nurse Educ. Today* **2020**, *91*, 104480, doi:10.1016/j.nedt.2020.104480.
21. Strametz, R.; Schneider, T.; Pitz, A.; Raspe, M. Survival-Day @ Wiesbaden business school – evaluation of a short-term educational intervention to reduce work-associated health risks during nursing internships of students in health care economics. *J. Occup. Med. Toxicol.* **2019**, *14*, 30, doi:10.1186/s12995-019-0251-z.
22. Yan, L.; Yao, L.; Li, Y.; Chen, H. Assessment and analysis of patient safety competency of Chinese nurses with associate degrees: A cross-sectional study. *Nurs. Open* **2020**; nop2.640; doi:10.1002/nop2.640.
23. da Rocha Seixas, L.; Gomes, A.S.; de Melo Filho, I.J. Effectiveness of gamification in the engagement of students. *Comput. Hum. Behav.* **2016**, *58*, 48–63, doi:10.1016/j.chb.2015.11.021.
24. Corvino, A.; Garzillo, E.; Arena, P.; Cioffi, A.; Monaco, M.G.L.; Lamberti, M. Augmented Reality for Health and Safety Training Program Among Healthcare Workers: An Attempt at a Critical Review of the Literature. In Proceedings of the Proceedings of the 1st International Conference on Human Systems Engineering and Design (IHSED2018): Future Trends and Applications, CHU-Université de Reims Champagne-Ardenne: France, 2019; p. 715.
25. Cárdenas-Robledo, L.A.; Peña-Ayala, A. Ubiquitous learning: A systematic review. *Telemat. Inform.* **2018**, *35*, 1097–1132, doi:10.1016/j.tele.2018.01.009.
26. Eyi, S.; Eyi, İ. Nursing Students' Occupational Health and Safety Problems in Surgical Clinical Practice. *SAGE Open* **2020**, *10*, 215824402090180, doi:10.1177/2158244020901801.
27. Earnshaw, R. From E-Learning to M-Learning-the use of Mixed Reality Games as a new Educational Paradigm. *Int. J. Interact. Mob. Technol.* **2011**, *5*, 17–25, doi:10.3991/ijim.v5i2.1463.

28. Yeh, Y.; Rega, E.M.; Chen, S.-Y. Enhancing creativity through aesthetics-integrated computer-based training: The effectiveness of a FACE approach and exploration of moderators. *Comput. Educ.* **2019**, *139*, 48–64, doi:10.1016/j.compedu.2019.05.007.
29. Hernández-García, I.; Cardoso, A. Hand hygiene compliance and determining factors among Spanish nursing students. *Am. J. Infect. Control.* **2013**, *41*, 943–944, doi:10.1016/j.ajic.2013.01.012.
30. Tumala, R.B.; Almazan, J.; Alabdulaziz, H.; Felemban, E.M.; Alsolami, F.; Alquwez, N.; Alshammari, F.; Tork, H.M.M.; Cruz, J.P. Assessment of nursing students perceptions of their training hospital's infection prevention climate: A multi-university study in Saudi Arabia. *Nurse Educ. Today* **2019**, *81*, 72–77, doi:10.1016/j.nedt.2019.07.003.
31. Graham, C.; Henrie, C.; Gibbons, A. Developing models and theory for blended learning research. In *Blended Learn. Res. Perspect.*; Picciano, A.G., Dziuban, C.D., Graham, C.R., Eds.; Routledge: New York, NY, USA, 2014; Volume 2, pp. 13–33.
32. Santamaría, J. Paradigmas de Investigación Educativa / Paradigms on Educational Research. *Entelequia Rev. Interdiscip.* **2013**, *16*, 91–102.
33. Stufflebeam, D.L. The CIPP Model for Evaluation. In *International Handbook of Educational Evaluation*; Kluwer International Handbooks of Education; Kellaghan, T., Stufflebeam, D.L., Eds.; Springer Netherlands: Dordrecht, The Netherlands, 2003; pp. 31–62, ISBN 978-94-010-0309-4.
34. Moreno-Fernandez, J.; Ochoa, J.J.; Lopez-Aliaga, I.; Alferez, M.J.M.; Gomez-Guzman, M.; Lopez-Ortega, S.; Diaz-Castro, J. Lockdown, Emotional Intelligence, Academic Engagement and Burnout in Pharmacy Students during the Quarantine. *Pharmacy* **2020**, *8*, 194, doi:10.3390/pharmacy8040194.
35. Orozco, M.M. Biohazard accidentality of nursing students in the university of applied and enviromental sciences U.D.C.AB. *Rev. UDCA Actual. Divulg. Científica* **2013**, *16*, 27–33.
36. Merino-de la Hoz, F.; Durá-Ros, M.J.; Rodríguez-Martín, E.; González-Gómez, S.; Mariano López-López, L.; Abajas-Bustillo, R.; de la Horra-Gutiérrez, I. Knowledge and adherence to bio-safety measures and biological accidents by nursing students during their clinical practice. *Enfermería Clínica* **2010**, *20*, 179–185, doi:10.1016/j.enfcli.2009.10.007.
37. Garrett, B.M.; Jackson, C. A mobile clinical e-portfolio for nursing and medical students, using wireless personal digital assistants (PDAs). *Nurse Educ. Today* **2006**, *26*, 647–654.
38. Lahti, M.; Hätönen, H.; Välimäki, M. Impact of e-learning on nurses' and student nurses knowledge, skills, and satisfaction: A systematic review and meta-analysis. *Int. J. Nurs. Stud.* **2014**, *51*, 136–149, doi:10.1016/j.ijnurstu.2012.12.017.
39. Bejan, A.; Xi, M.; Parker, D.L. Outcomes of a Safety and Health Educational Intervention in Auto Body and Machine Tool Technologies Vocational College Programs: The Technical Education Curricula for Health and Safety (TECHS) Study. *Ann. Work Expos. Health* **2020**, *64*, 185–201, doi:10.1093/annweh/wxz092.
40. Kintu, M.J.; Zhu, C.; Kagambe, E. Blended learning effectiveness: The relationship between student characteristics, design features and outcomes. *Int. J. Educ. Technol. High Educ.* **2017**, *14*, 7, doi:10.1186/s41239-017-0043-4.

41. Wang, S.-G.; Hung, C.-T.; Li, S.-F.; Lu, Y.-C.; Chang, S.-C.; Lee, H.-M.; Pai, L.-W.; Lai, F.-I.; Huang, Y.-W.; Chung, Y.-C. Incidence of ambulatory care visits after needlestick and sharps injuries among healthcare workers in Taiwan: A nationwide population-based study. *Kaohsiung J. Med. Sci.* **2014**, *30*, 477–483, doi:10.1016/j.kjms.2014.05.004.
42. de Almeida, M.C.M.; da Canini, S.R.M.S.; Reis, R.K.; Toffano, S.E.M.; Pereira, F.M.V.; Gir, E. Clinical treatment adherence of health care workers and students exposed to potentially infectious biological material. *Rev. Esc. Enferm. USP.* **2015**, *49*, 261–266, doi:10.1590/S0080-623420150000200011.
43. Erawati, M.; Andriany, M. The Prevalence and Demographic Risk Factors for Latent Tuberculosis Infection (LTBI) Among Healthcare Workers in Semarang, Indonesia. *J. Multidiscip. Healthc.* **2020**, *13*, 197–206, doi:10.2147/JMDH.S241972.
44. Arcanjo, R.V.G.; Christovam, B.P.; de Souza, N.V.D.O.; Silvino, Z.R.; Da Costa, T.F. Knowledge and practices of nursing workers on occupational risks in primary health care: An intervention trial. *Enfermería Glob.* **2018**, *17*, 200, doi:10.6018/eglobal.17.3.294821.
45. Nykänen, M.; Puro, V.; Tiikkaja, M.; Kannisto, H.; Lantto, E.; Simpura, F.; Uusitalo, J.; Lukander, K.; Räsänen, T.; Teperi, A.-M. Evaluation of the efficacy of a virtual reality-based safety training and human factors training method: Study protocol for a randomised-controlled trial. *Inj. Prev.* **2020**, *26*, 360–369, doi:10.1136/injuryprev-2019-043304.
46. Barisone, M.; Bagnasco, A.; Aleo, G.; Catania, G.; Bona, M.; Gabriele Scaglia, S.; Zanini, M.; Timmins, F.; Sasso, L. The effectiveness of web-based learning in supporting the development of nursing students' practical skills during clinical placements: A qualitative study. *Nurse Educ. Pract.* **2019**, *37*, 56–61, doi:10.1016/j.nepr.2019.02.009.

Chapter VI. Training healthcare workers using an educational technological approach: A preliminary study

Chapter VI. Training healthcare workers using an educational, technological approach: a preliminary study

Esther Vaquero-Álvarez[1] Gerardo Perdros-Perez[1], Manuel Vaquero-Abellán[2,3], Pilar Martinez-Jimenez[1], María Dolores Redel Mecías [4] and Pilar Aparicio-Martínez [2,3]

[1] Simulation models in energy, transport, physics, engineering, occupational hazard researcher Group, Junta de Andalucía, and Dpt. Applied Physics, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, Spain; z12vaalm@uco.es, fa1pepeg@uco.es; fa1majip@uco.es

[2] GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; n32apmap@uco.es (P.A.M.); en1vaabm@uco.es (M.V.A.);

[3] Departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, Córdoba, Spain; n32apmap@uco.es (P.A.M.); en1vaabm@uco.es (M.V.A.);

[4] Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ig1remam@uco.es (M.D.R.-M.)

Abstract: Healthcare workers are exposed to different biological pathogens, which implies a risk to their health and cost to the system. In this population, the rate of accidents and diseases related to work is higher than desired (up to 3.2%). The exposure of these agents depends on a series of factors, among which the preventive interventions carried out stand out as a critical point. Airborne pathogens and, therefore, chronic respiratory diseases, such as tuberculosis, are highly contagious and have severe effects on the workers' health, such as Mycobacterium tuberculosis or the sars-covid-19. The symptoms take time to manifest, and the driveway is the airways, which allows the worker not to notice the exposure after the symptoms start to begin. Several educational plans have been generated and implemented to raise awareness among healthcare workers regarding risk and prevention; simultaneously, organizations and political structures have created prevention policies and updated guidelines.

Nevertheless, previous studies have highlighted that the training and education among healthcare workers are reduced despite the programs created and their cost. Simultaneously, creating more attractive environments for training has been developed in the health field to improve healthcare workers' knowledge and skills, such as virtual environments for surgeries. Despite technological tools and approaches in the health field, creating an educational program using technological still lacks. The current study had an objective to develop and integrate an occupational health and safety learning methodology based on a technological approach focusing on healthcare workers. The design and diagram of the creation were based on the fourth pillar of any educational platform: feedback, appealing experience, creative design, and assessment of the

designed program. The platform was based on gamification as an effective method for adopting this platform's adaptation and valuation as a prevention learning tool. The design of this virtual learning system aims to stimulate knowledge acquisition with a more dynamic teaching process. The prototype's initial evaluation was the context, input, process, and product (CIPP) method, by which seven specialists in occupational health and safety and ten in computational systems. The results showed that the prototype was highly defined, but more profound modifications of the context and process were needed, especially for improving appeal and usefulness (5/7). The current study continues to be developed, and future implications will be the integration and use among the end user's healthcare workers to determine the usability of the technological approach created.

Keywords: gamification; VLs; healthcare workers; biological agents

VI.1. Introduction

Healthcare workers are exposed to different biological pathogens, which implies a risk to their health and cost to the system. In this population, the rate of accidents and diseases related to work is higher than desired (up to 3.2%)[1–3]. The exposure of these agents depends on a series of factors, among which the preventive interventions carried out stand out as a critical point[4]. Airborne pathogens and, therefore, chronic respiratory diseases[2,5], such as tuberculosis, are highly contagious and have severe effects on the workers' health, such as *Mycobacterium tuberculosis* [6,7], or the sars-covid-2 and posterior sickness Covid-19. The symptoms take time to manifest, and the driveway is the airways[5], which allows the worker not to notice the exposure after the symptoms start to begin. Several educational plans have been generated and implemented to raise awareness among healthcare workers regarding risk and prevention[8,9]; simultaneously, organizations and political structures have created prevention policies and updated guidelines[10,11].

Nevertheless, previous studies have highlighted that healthcare workers' training and education are reduced despite the programs created and their cost [12,13]. Several studies have indicated how the protocols or guidelines seem satisfactory, but healthcare workers continue to lack training, knowledge, or inadequate safety culture[14–16]. In this line, different organizations like the World Health Organization have stated that one missing resource in the safety culture is integrating technical advances[17]. Although at the same, there have been created more attractive environments, these have focused on training skills, such as virtual environments for surgeries[18,19]. Additionally, the formation and Communication Technologies (ICTs) have become a pillar tool of the healthcare systems, integrating the prevention or treatment of

patients[9,20]. The necessity of adequate ICTs and its potential has been highlighted especially in the pandemic, by which ICTs have gained more relevance and functions, such as surveillance or monitoring of the sociodemographic conditions, improving the efficiency of medical procedures, or facilitating rapid response in this time of global crises[21,22].

Nevertheless, the creation of ICTs for workers needs to have in mind the need of the user and their opinion and the correction integration of it the working or learning environment[23]. Despite technological tools and approaches in the health field, creating an educational program using technological still for improving the knowledge and training of healthcare workers counties is lacking[24]. Therefore, the current study had as an objective the development and integration of an occupational health and safety learning methodology based on a technological approach focusing on healthcare workers via the platform's prototype.

VI.2. Materials and Methods

VI.2.1.Design

The research is an observational traversal study focusing on assessing the first phase before developing a web-based platform. The assessment of the web's initial stage was based on the results from the analysis data, and previous researches have made regarding new technologies as interventions in occupational safety[25–27].

VI.2.2. Methodological approach and assessment

The prototype's initial evaluation was based on the context, input, process, and product (CIPP) method [28], by which seven specialists in the occupational health and safety, and ten computational systems, and engineering professionals carried out.

According to the CIPP method, developed by Stufflebeam, 2003, the evaluation should consider four issues: context, input, process, and product. The initial assessment focused on evaluating the technology functionally, and the pedagogical tool was oriented by this method to determine by focal groups the area of improvement and preferences of the end-users. It was used as a survey to carry out a double study orientated to the professionals from an occupational safety or educational background and a to engineering or computational experts.

VI.2.3. Pilot development of the platform

The platform's initial design (Figure 1) followed a structure of levels and layers between the elements created. The main elements focused on an initial screen with information and the logos

that moved to the main stage with the platform sections formed by tutorials, galleries, virtual laboratories (VLs), and videos.

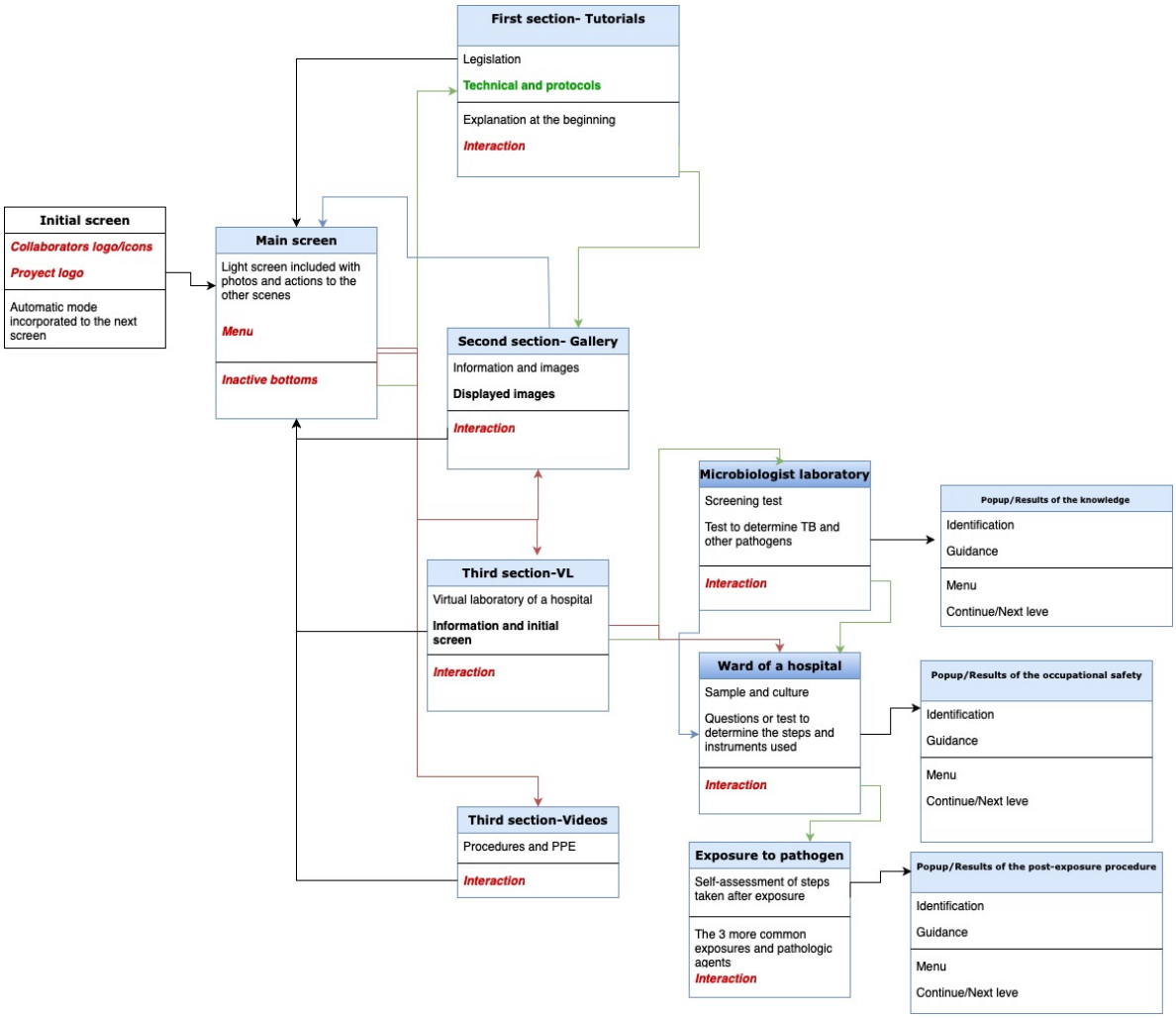


Figure 1. Flow diragram of the sections and layers

Each section was confirmed by information and the use of images (Figure 2), although the tutorials search for a distinction with the other sections since these tutorials would be focused on guidelines, protocols, and legislation. Meanwhile, the gallery, videos, and VLs combined information and images and gamification, especially for the VLs (Figure 3), to promote a more attractive and appealing environment to get the user's attention.

Figure 2. Main screen with the distion of the sections

In the gallery's case, the idea is to use a combination of real images, explanations, and further information, focusing on instruments, personal protective equipment, and occupational measures. The VLs focused on an interactive environment to promote feedback as the user moves from each stage and continues into the same training level (Figure 1 and 3). For this purpose, in the beginning, it was established to use Genial.ly as the primary system of coding for the gamification of the structure, focusing on HTML5. However, as the platform's framing, MySQL, PHP, and C. Genial.ly has been used since it an online software based on HTML5 and CakePHP that allows the user to create animations and scenes more dynamic, integrative, and interactive, and without programming knowledge.

Figure 3. VLs based on gamification

VI.2.4. Instruments and sample

The survey created was based on the work of Stufflebeam in 2003, divided into five sections. The survey was structured in sociodemographic data, background, opinion regarding the structure via the flow diagram (Figure 1) or main screen (Figure 3), zones of improvements, and evaluation of the web platform's initial structure. The survey was segmented into two depending on the volunteer's profile, an engineering or occupational safety background.

The survey was distributed in the first week of December via Google forms and throw instant messenger, although the participants kept in all moment their anonymity, and it was voluntary. The survey for the technicians (https://forms.gle/QvFRE7zhEjznc9N7A) and occupational safety and teaching professionals (https://forms.gle/chZpUE7W2KtYLeav5).

VI.3. Results

The initial assessments showed differences regarding the profile of the focal group, the age, and opinion. The volunteers' mean age was 45.28 for occupational safety or teaching professionals (O/TP) and 43 years old for the workers with an engineering background (Table 1). From the technical side, all of the participants were from an engineering background, 20% from informatics, and 20% from an agriculture background. Meanwhile, the professionals were most of the lecturers and teachers (57.1%), and 28.6% were occupational safety and health graduates. Regarding the years of experience, the technical users had more than ten years (100%), which was similar to the professionals with ten years (60%), from two to five years (20%) and the less than one or from six to ten years (10% each).

Table 1. Initial data from the samples

Variables	Technical survey(N=10)	Professional survey(N=7)
Age	30.0% (20-30 range)	42.9% (40-50 range)
Sex	80% (Male)	50% (Female and Male)
Background	Engineering (100%), 20% from informatics	57.1% (Lectures and teaching)
Experience	100% (more than ten years)	60% (more than ten years)

The professionals and technicians showed several areas of improvement and changes regarding the structure, cohesion, and segments. In the case of participants with a more technical

background, the area that needs more modification was the section and segmentation in the levels (30%) and the thematic (30%), followed by the organization of the resources (20%) and interaction between stages (20%). Meanwhile, the professionals indicated how the area with the need for significant improvement was the main screen (28.6%), and moderate change was the colors or pallet used 28.6%). The technicians indicated that the structure needs further modifications before creating the web platform (40%), and the professionals indicated the need for help and the appeal of the platform (42.9%).

The professionals focused on occupational safety and teaching were asked about the rate of information and images in tutorials, galleries, videos, and VLs (Table 2). The results showed that the more common combination independently of the section was 25% of information and 75% of visual content and interactivity, followed by the option of 50 percent of information and visual content. Additionally, the less common option was zero percentage of information and all based on visual content, being only selected for one participant for the gallery of images and videos.

Table 2. Opinion regarding the information and images

Section of the platform	0% information/ 100% visual content and interactivity	25% information/ 75% visual content and interactivity	50% information/ 50% visual content and interactivity	75% information/ 25% visual content and interactivity	100% information/ 0% visual content and interactivity
Gallery	14.3%	42.9%	42.9%	0%	0%
Tutorials	0%	57.1%	28.6%	14.3%	0%
VLs	0%	57.1%	28.6%	14.3%	0%
Videos	14.3%	57.1%	14.3%	14.3%	0%

Finally, both the technicians and occupational safety or teaching professionals (O/TP) indicated the evaluation of the initially proposed platform (Table 3). Both populations studied the main pillars showed differences regarding their opinion, although all participants (N=17) did not indicate that the initial platform was really bad design, organize, or created regarding functionality or interactivity.

Table 3. Opinion regarding the initial pilot

Area	Really bad	Bad	Normal	Pretty good	Really good
Functionality	0% of TP[1]	0% of TP[1]	10%	30 % of TP[1]	60% of TP[1]
	0% of O/TP[2]	0% of O/TP[2]	28.6% of O/TP[2]	14.3% of O/TP[2]	57.1% of O/TP[2]

Design	0% of TP[1]	10% of TP[1]	0%	20 % of TP[1]	70% of TP[1]
	0% of O/TP[2]	0% of O/TP[2]	28.6% of O/TP[2]	14.3% of O/TP[2]	57.1% of O/TP[2]
Organization	0% of TP[1]	0% of TP[1]	10% of TP[1]	30 % of TP[1]	60% of TP[1]
	0% of O/TP[2]	0% of O/TP[2]	28.6% of O/TP[2]	14.3% of O/TP[2]	57.1% of O/TP[2]
Interactivity	0% of TP[1]	10% of TP[1]	0%	40 % of TP[1]	50% of TP[1]
	0% of O/TP[2]	0% of O/TP[2]	28.6% of O/TP[2]	14.3% of O/TP[2]	57.1% of O/TP[2]

[1] Technical professional: TP

[2] Occupational safety or teaching professional: O/TP

The results regarding the occupational safety or teaching professionals showed the same evaluation independently of the section evaluated. This exact evaluation did not occur with the technicians whose opinion changed according to the section evaluated, e.g., the design or interactivity, defined as bad by 10% of the sample (1 out 7 participants).

VI.4. Discussion

The platform's initial pilot was globally well evaluated, although there were differences between the opinion from technical and occupational safety or teaching participants. In this sense, the engineering volunteers showed that the improvements need to be done regarding the design's depth and the interconnection between the section, e.g., tutorials and video.

This technical approach is similar to previous studies, in which the points to determine focused on the links, navigation, and organization[29,30], which diverse from the end-user point of view. In the user's case, numerous studies have highlighted that the design and functionality are licked to better, and counties use[31–33]. An interesting idea was the help in the VLs and the main screen, which could be integrated as constant elements but that the constant feedback would be negative for the user and the manager of content [34]. Another aspect that could be further developed would be integrating virtual reality (VR), which could allow a more profound integration of the trainer in the learning experience. The VR has some advantages against the VLs, such as a more appealing experience, a more concise caption of the user's attention, or a more integrative environment. In this sense, few researchers have created VR environments to increase knowledge and practical skills[35,36]. In this sense, from the technician's point of view, the participants indicated integrating a feedback system, e.g., logging or history of the user, developing the VR, and using VR headset or sensor for degerming the correct procedures. To carry out these changes, some technicians (two of ten) indicated the possibility of carrying out two versions for a platform based on VLs and JavaScript, and other based on VR headset and developed in C coding or JASON.

Another exciting aspect was that the participants with knowledge in the occupational safety or teaching field preferred, in almost all cases, little information and more visual contact and interactivity. These results seemed to match with other studies in workers or students, whose preference was little information and more training based on visual and interactive approaches than relatively constant information[37,38]. Additionally, because of the impossibility of training in a controlled environment and the platform's presence, virtual learning seems to be more attractive to the end-user, as it has been showing with social media[39] and how the participants also indicated that it needs improvement. Despite the area of improvements and differences between samples, the participants' opinion indicated that the platform's initial prototype was well described and evaluated, which could be useful in the future. As with any research, the present study has limitations, being the main one that the focus groups were limited and from a range of age higher than desired. As future research, the next step will be developing the platform using the data provided from the participants to create a more dynamic structure and organization, providing a help element and more feedback via activities and gamification. To achieve the future objective, the platform would be developed to collaborate with professionals from the area of engineering, occupational safety, and the teaching field.

VI.5. Conclusions

The results showed that the prototype was highly defined, but more profound modifications of the context and process were needed, especially for improving appeal and usefulness. The current study continues to be developed, and future implications will be the integration and use among end-user groups of healthcare workers to determine the usability of the technological approach created.

References

1. Kimman, T.G.; Smit, E.; Klein, M.R. Evidence-based biosafety: a review of the principles and effectiveness of microbiological containment measures. *Clin Microbiol Rev* **2008**, *21*, 403–425, doi:10.1128/CMR.00014-08.

2. Takayanagi, Noboru Biological agents and respiratory infections: Causative mechanisms and practice management. *Respiratory Investigation* **2015**, *53*, 185–200, doi:10.1016/j.resinv.2015.03.003.

3. Carvalho, D.C. de; Rocha, J.C. da; Gimenes, M.C. de A.; Santos, E.C.; Valim, M.D. Work incidents with biological material in the nursing team of a hospital in Mid-Western Brazil. *Escola Anna Nery* **2017**, *22*.

4. Tagliani, E.; Anthony, R.; Kohl, T.A.; de Neeling, A.; Nikolayevskyy, V.; Ködmön, C.; Maurer, F.P.; Niemann, S.; van Soolingen, D.; van der Werf, MJ; et al. use of a Whole Genome Sequencing-based approach for Mycobacterium tuberculosis surveillance in Europe in 2017–2019: an ECDC pilot study. *Eur Respir J* **2020**, 2002272, doi:10.1183/13993003.02272-2020.

5. Aliabadi, A.A.; Rogak, S.N.; Bartlett, K.H.; Green, SI. Preventing Airborne Disease Transmission: Review of Methods for Ventilation Design in Health Care Facilities. *Advances in Preventive Medicine* **2011**, *2011*, 124064, doi:10.4061/2011/124064.

6. Bonville, C.; Domachowske, J. Tuberculosis. In *Vaccines: A Clinical Overview and Practical Guide*; Domachowske, J., Suryadevara, M., Eds.; Springer International Publishing: Cham, 2021; pp. 363–372 ISBN 978-3-030-58414-6.

7. Hatherill, M.; White, R.G.; Hawn, T.R. Clinical Development of New TB Vaccines: Recent Advances and Next Steps. *Frontiers in Microbiology* **2020**, *10*, 3154, doi:10.3389/fmicb.2019.03154.

8. Centers for Disease Control and Prevention (CDC) Plan to combat extensively drug-resistant tuberculosis: recommendations of the Federal Tuberculosis Task Force. *MMWR Recomm Rep* **2009**, *58*, 1–43.

9. Bianchini, A.; Donini, F.; Pellegrini, M.; Saccani, C. An innovative methodology for measuring the effective implementation of an Occupational Health and Safety Management System in the European Union. *Saf. Sci.* **2017**, *92*, 26–33, doi:10.1016/j.ssci.2016.09.012.

10. Beggs, C.B.; Kerr, K.G.; Donnelly, J.K.; Sleigh, P.A.; Mara, D.D.; Cairns, G. An engineering approach to the control of Mycobacterium tuberculosis and other airborne pathogens: a UK hospital based pilot study. *Trans Roy Soc Trop Med Hyg* **2000**, *94*, 141–146, doi:10.1016/S0035-9203(00)90250-5.

11. McDiarmid, M.A.; Condon, M. Organizational Safety Culture/Climate and Worker Compliance With Hazardous Drug Guidelines: Lessons From The Blood-Borne Pathogen Experience. *Journal of Occupational and Environmental Medicine* **2005**, *47*.

12. Boucaut, R.; Knobben, L. Occupational health and safety incidents at a university school of nursing: A retrospective, descriptive appraisal. *Nurse Education in Practice* **2020**, *44*, 102776, doi:10.1016/j.nepr.2020.102776.

13. Rusu-Zagar, G.; Iorga, I.; Anghel, SO; Rusu-Zagar, C. Occupational Safety and Health in National Education. *Procedia - Social and Behavioral Sciences* **2013**, *92*, 832–837, doi:10.1016/j.sbspro.2013.08.762.

14. Giménez-Marín, A.; Rivas-Ruiz, F.; García-Raja, A.M.; Venta-Obaya, R.; Fusté-Ventosa, M.; Caballé-Martín, I.; Benítez-Estevez, A.; Quinteiro-García, A.I.; Bedini, J.L.; León-Justel, A.; et al. Assessment of patient safety culture in clinical laboratories in the Spanish National Health System. *Biochem Medica* **2015**, *25*, 363–376, doi:10.11613/bm.2015.036.

15. Kim, Y.; Park, J.; Park, M. Creating a Culture of Prevention in Occupational Safety and Health Practice. *Saf Health Work* **2016**, *7*, 89–96, doi:10.1016/j.shaw.2016.02.002.

16. Arcanjo, RVG; Christovam, B.P.; Souza, N.V.D. de O.; Silvino, Z.R.; Da Costa, T.F. Knowledge and practices of nursing workers on occupational risks in primary health care: an intervention trial. *Enfermería Global* **2018**, *17*, 200, doi:10.6018/eglobal.17.3.294821.

17. Wilburn, S.Q.; Eijkemans, G. Preventing Needlestick Injuries among Healthcare Workers: A WHO-ICN Collaboration. *null* **2004**, *10*, 451–456, doi:10.1179/oeh.2004.10.4.451.

18. Button, D.; Harrington, A.; Belan, I. E-learning & information communication technology (ICT) in nursing education: A review of the literature. *Nurse Educ Today* **2014**, *34*, 1311–1323, doi:10.1016/j.nedt.2013.05.002.

19. E. Mattila; J. Koskelo; R. Lappalainen; J. Salminen; P. Nyman; J. Lahteenmaki; T. Leino; I. Korhonen A Concept for ICT Assisted Health Promotion in the Occupational Healthcare. In Proceedings of the 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2007; pp. 1786–1789.

20. Nacke, B.; Beintner, I.; Görlich, D.; Vollert, B.; Schmidt-Hantke, J.; Hütter, K.; Taylor, C.B.; Jacobi, C. everyBody–Tailored online health promotion and eating disorder prevention for women: Study protocol of a dissemination trial. *Internet Interventions* **2019**, *16*, 20–25, doi:10.1016/j.invent.2018.02.008.

21. Li, J.; Seale, H.; Ray, P.; Wang, Q.; Yang, P.; Li, S.; Zhang, Y.; MacIntyre, C.R. e-Health preparedness assessment in the context of an influenza pandemic: a qualitative study in China. *BMJ Open* **2013**, *3*, e002293, doi:10.1136/bmjopen-2012-002293.

22. Thilakarathne, N.N.; Kagita, M.K.; Reddy, T.; Maddikunta, P.K.R. The Adoption of ICT Powered Healthcare Technologies towards Managing Global Pandemics. *Cornell University* **2020**, 20.

23. Rubio-Romero, J.C.; Arquillos, A.; Suárez-Cebador, M.; Carrillo-Castrillo, J. Information and Communication Technologies (ICT) in Occupational Health and Safety (OHS) courses at engineering under/degree studies. In *Occupational Safety and Hygiene*; CRC Press, 2014; pp. 49–52 ISBN 978-1-138-00144-2.

24. Deuffic-Burban, S.; Delarocque-Astagneau, E.; Abiteboul, D.; Bouvet, E.; Yazdanpanah, Y. Blood-borne viruses in health care workers: Prevention and management. *J Clin Virol.* **2011**, *52*, 4–10, doi:10.1016/j.jcv.2011.05.016.

25. Bennett, M.P.; Lovan, S.; Hager, K.; Canonica, L.; Taylor, B. A one hour teaching intervention can improve end-of-life care. *Nurs Educ Today* **2018**, *67*, 93–99, doi:10.1016/j.nedt.2018.05.010.

26. Yu, K.; C. Pope, S.; Perez, M. Clinical Treatment and Practice Recommendations for Disordered Eating in Asian Americans. *Prof Psychol-Res Pr* **2019**, doi:10.1037/pro0000244.

27. Amry, AB The impact of whatsapp mobile social learning on the achievement and attitudes of female students compared with face to face learning in the classroom. *European Scientific Journal* **2014**, *10*, 116–136.

28. Stufflebeam, D.L. The CIPP Model for Evaluation. In *International Handbook of Educational Evaluation*; Kellaghan, T., Stufflebeam, D.L., Eds.; Springer Netherlands: Dordrecht, 2003; pp. 31–62 ISBN 978-94-010-0309-4.

29. Limosani, R.; Esposito, R.; Manzi, A.; Teti, G.; Cavallo, F.; Dario, P. Robotic delivery service in combined outdoor–indoor environments: technical analysis and user evaluation. *Robotics and Autonomous Systems* **2018**, *103*, 56–67, doi:10.1016/j.robot.2018.02.001.

30. Simões, J.; Redondo, R.D.; Vilas, A.F. A social gamification framework for a K-6 learning platform. *Comput Hum Behav* **2013**, *29*, 345–353, doi:10.1016/j.chb.2012.06.007.

31. da Rocha Seixas, L.; Gomes, A.S.; de Melo Filho, IJ Effectiveness of gamification in the engagement of students. *Comput Hum Behav* **2016**, *58*, 48–63, doi:10.1016/j.chb.2015.11.021.

32. Barisone, M.; Bagnasco, A.; Aleo, G.; Catania, G.; Bona, M.; Gabriele Scaglia, S.; Zanini, M.; Timmins, F.; Sasso, L. The effectiveness of web-based learning in supporting the development of nursing students' practical skills during clinical placements: A qualitative study. *Nurse Educ Pract* **2019**, *37*, 56–61, doi:10.1016/j.nepr.2019.02.009.

33. Anwar, M.M.; Liu, C.; Li, J. Discovering and tracking query oriented active online social groups in dynamic information network. *World Wide Web* **2019**, *22*, 1819–1854, doi:10.1007/s11280-018-0627-5.

34. Bahn, S.; Barratt-Pugh, L. Emerging Issues of Health and Safety Training Delivery in Australia: Quality and Transferability. *Procedia - Social and Behavioral Sciences* **2012**, *62*, 213–222, doi:10.1016/j.sbspro.2012.09.035.

35. Jara, C.A.; Candelas, F.A.; Torres, F.; Dormido, S.; Esquembre, F.; Reinoso, O. Real-time collaboration of virtual laboratories through the Internet. *Comput Educ* **2009**, *52*, 126–140, doi:10.1016/j.compedu.2008.07.007.

36. Nykänen, M.; Puro, V.; Tiikkaja, M.; Kannisto, H.; Lantto, E.; Simpura, F.; Uusitalo, J.; Lukander, K.; Räsänen, T.; Teperi, A.-M. Evaluation of the efficacy of a virtual reality-based safety training and human factors training method: study protocol for a randomised-controlled trial. *Inj Prev* **2020**, *26*, 360–369, doi:10.1136/injuryprev-2019-043304.

37. Floyde, A.; Lawson, G.; Shalloe, S.; Eastgate, R.; D'Cruz, M. The design and implementation of knowledge management systems and e-learning for improved occupational health and safety in small to medium sized enterprises. *Safety Science* **2013**, *60*, 69–76, doi:10.1016/j.ssci.2013.06.012.

38. Corvino, A.; Garzillo, E.; Arena, P.; Cioffi, A.; Monaco, M.G.L.; Lamberti, M. Augmented Reality for Health and Safety Training Program Among Healthcare Workers: An Attempt at a Critical Review of the Literature. In Proceedings of the Proceedings of the 1st International Conference on Human Systems Engineering and Design (IHSED2018): Future Trends and Applications; CHU-Université de Reims Champagne-Ardenne, France, 2019; p. 715.

39. Vaterlaus, J.M.; Patten, E.V.; Roche, C.; Young, J.A. #Gettinghealthy: The perceived influence of social media on young adult health behaviors. *Comput Hum Behav* **2015**, *45*, 151–157, doi:10.1016/j.chb.2014.12.013.

VII. Conclusions and future research

VII.I. Conclusions

The first main result of this thesis has been the study of the tendency of publication regarding ICTs, occupational safety and health in the healthcare sector, especially the relationship with the safety among healthcare workers. From this chapter, it can be concluded the increasing number of publications about. This analysis has showed more connexions between countries and authors in researching in the health field prevention and screening, although it seems that the most significant development of ICTs for this field is yet to come. Additionally, the results have highlighted the need for more studies focused on ICTs' negative effect on healthcare workers.

From the following chapter, it can be concluded the relationship between measures at work in the mycobacteriology laboratories, knowledge, experience, personal protective equipment, and training is insufficient. This chapter of the thesis reflects the dilemma or dichotomy in the current laboratories, comparing the national with international, lacked training, the amount of work, and how the workers followed the relevant protocols. This chapter reflected that the behaviours and hygiene of the Spanish workers remain unsafe and poor compared to those of other European workers. Although in both among Spanish and international workers, in Europe, North America and South America, the exposure to airborne pathogens may be related to the lack of continuous training and education.

From the comparison of the protocols between Spain and Germany, both countries have committed to establishing tuberculosis prevention guidelines in order to achieve the objectives proposed by the WHO at the global level, coinciding in the notification of cases, chemoprophylaxis and treatment of latent tuberculosis. They also agree on diagnostic methods, whose objective is to reduce the number of cases and help patients in the event of a possible infection, individualized assessment and subsequent follow-up to confirm the diagnosis in people in risky circumstances derived from socioeconomic conditions, homeless, children from countries with a high incidence of TB in adoption or migration processes. The two nations share common actions in patient education, the search for the best treatments and the care of patients and their families by a multidisciplinary team training, work overload and the way in which workers followed the relevant protocols.

Our findings suggest that in order to reduce the prevalence of tuberculosis and the risk among workers, greater compliance with the regulations on safety and health at work, monitoring of preventive measures and carrying out more research focused on monitoring such measures is necessary.

The next chapter showed the efficacy of educational programs focused on a technological approach. The new teaching methodologies based on ICT as a mixed model improve the culture and knowledge of prevention among students and future health professionals. The evaluation of the platform showed that the opinion of the users on the inclusion of this educational approach based on technology was satisfactory. Subsequent analysis of basic knowledge and of the incidence of biological accidents have shown the potential of the platform as a useful and practical preventive tool for specialization and of the different healthcare professionals how this approach could also use it for their ongoing training. Subsequent analysis of basic knowledge and of the incidence of biological accidents have shown the potential of the platform as a useful and practical preventive tool for specialization and of the different professional categories that participate in the laboratories; They could also use it for their ongoing training. Based on the results, it could be concluded that it is necessary to include the use of ICTs in occupational health and safety, as well as specific protocols or technological tools.

Therefore, the last chapter was the assessment of initial version of a platform via technicians and professionals from the OSH and teaching sector. The platform has been designed to include different segments, such as a Virtual Laboratory (LV), using a gamification via Genial.ly. This platform has as final purpose the creation of a virtual online learning experience for improving knowledge of the risks of exposed workers, as well as the main control and prevention measures for pathogens. The assessment of the initial protype showed areas of improvements regarding the organization and a more appealing appearance, although most of the participants indicated that the different areas, such as organization or design, indicated that was good or really good. The evaluation of the platform showed that the opinion of the users on the initial platform focusing on an educational and technological approach seemed satisfactory. In this sense, the different educational platforms seem to be useful to young people to train, for the working place and wellbeing.

VII.2. Future research

More work will need to be done to determine the grade of inclusion or usage of ICTs for occupational health and safety among healthcare workers and organizations. In this sense, the future studies will expand research about the effectiveness of the platform in development, for the reduction of risk exposures and preventing workplace accidents. Investigate these new interactive learning methodologies and choose different guidelines that integrate gamification, virtual reality and artificial intelligence.

One the objectives initially, proposed regarding the measurement of ventilation necessary for certain exposures in spaces such as laboratories, primary care consultations or emergency centres, it will be the subject of future research since with the Covid-19 pandemic has limited the accomplishment of this objective. Finally, to complete the objectives proposed in the thesis, the chapters not published are under revision and will be published as paper or conference papers.

Conclusiones y futura investigación

Conclusiones

Existe un número creciente de publicaciones sobre las TIC, la seguridad y la salud ocupacional en el sector sanitario, aunque parece que el desarrollo más significativo de las TIC para este campo está aún por venir. Los resultados de un análisis bibliométrico han puesto de manifiesto la necesidad de realizar más estudios centrados en el efecto negativo de las TIC en los trabajadores de la salud.

Los comportamientos y las medidas higiénicas de los trabajadores españoles siguen siendo inseguros y pobres en comparación con los de otros trabajadores europeos. Aunque tanto en los trabajadores españoles como en los de otros países europeos, de América del Norte y América del Sur, los riesgos derivados de la exposición a los patógenos transmitidos por el aire pueden estar relacionados con la falta de formación y educación continua.

Para reducir el riesgo entre los trabajadores, es necesario un mayor cumplimiento de las normas de seguridad y salud en el trabajo, la vigilancia de las medidas preventivas y la realización de más investigaciones centradas en la supervisión de dichas medidas.

Alemania y España comparten acciones comunes en la educación del paciente, la búsqueda de los mejores tratamientos y el cuidado de los pacientes y sus familias por un equipo multidisciplinar. También coinciden en la importancia de la formación, evitar sobrecarga de trabajo y la forma en que los trabajadores siguieron los protocolos pertinentes.

Las nuevas metodologías de enseñanza, basadas en las TIC como modelo mixto, mejoran la cultura y el conocimiento de la prevención entre los estudiantes y los futuros profesionales de la salud.

Se ha diseñado la versión inicial de un Laboratorio Virtual (LV) en una plataforma que incluye diferentes escenarios de exposición a agentes biológicos, y tiene el propósito de crear una experiencia virtual de aprendizaje en línea para mejorar el conocimiento de los riesgos de los trabajadores expuestos, así como las principales medidas de control y prevención de los patógenos. La evaluación de la plataforma mostró que la opinión de los usuarios sobre la inclusión de este enfoque educativo basado en la tecnología es satisfactoria.

X.2. **Futuras investigaciones**

Hay que seguir trabajando para determinar el grado de inclusión o utilización de las TIC para la salud y la seguridad en el trabajo entre los trabajadores y las organizaciones de atención de la salud. En este sentido, los futuros estudios ampliarán la investigación sobre la eficacia de la plataforma en desarrollo, para la reducción de la exposición a riesgos y la prevención de accidentes laborales. Asimismo, se investigarán estas nuevas metodologías de aprendizaje interactivo y se elegirán diferentes pautas que integren la gamificación, la realidad virtual y la inteligencia artificial.

Uno de los objetivos inicialmente propuestos en relación con la medida de la ventilación necesaria para determinadas exposiciones en espacios como laboratorios, consultas de atención primaria o centros de emergencia, será objeto de futuras investigaciones, ya que con la pandemia de Covid-19 se ha limitado el cumplimiento de este objetivo.

Por último, para completar los objetivos propuestos en la tesis, los capítulos no publicados están en proceso de revisión o en fase inicial de aceptación y se publicarán como artículos o contribuciones as congresos.

Schlussfolgerungen und Zukünftige Forschungsarbeiten

Schlussfolgerungen

Das erste Hauptergebnis dieser Arbeit war die Untersuchung des Publikationstrends in Bezug auf IKT, Sicherheit und Gesundheit am Arbeitsplatz im Gesundheitssektor, insbesondere die Beziehung zur Sicherheit der Beschäftigten im Gesundheitswesen. Aus diesem Kapitel lässt sich die wachsende Zahl von Publikationen zu diesem Thema schließen. Diese Analyse hat mehr Verbindungen zwischen Ländern und Autoren in der Forschung im Bereich Gesundheit, Prävention und Screening aufgezeigt, obwohl es scheint, dass die wichtigste Entwicklung der IKT für diesen Bereich noch aussteht. Darüber hinaus haben die Ergebnisse gezeigt, dass mehr Studien erforderlich sind, die sich auf die negativen Auswirkungen der IKT auf das Gesundheitspersonal konzentrieren.

Das folgende Kapitel zeigt, dass der Zusammenhang zwischen Maßnahmen bei der Arbeit in mykobakteriologischen Laboratorien, Wissen, Erfahrung, persönlicher Schutzausrüstung und Ausbildung unzureichend ist. Dieses Kapitel der Dissertation reflektiert das Dilemma oder die Dichotomie in den heutigen Laboratorien und vergleicht das nationale mit dem internationalen, den Mangel an Ausbildung, den Arbeitsaufwand und die Art und Weise, wie die Arbeiter die entsprechenden Protokolle befolgten. Dieses Kapitel spiegelt wider, dass das Verhalten und die Hygiene der spanischen Arbeitnehmer im Vergleich zu anderen europäischen Arbeitnehmern immer noch unsicher und schlecht ist. Obwohl sowohl spanische als auch internationale Arbeitnehmer in Europa, Nord- und Südamerika einer Belastung durch luftübertragene Krankheitserreger ausgesetzt sind, kann dies mit einem Mangel an Aus- und Weiterbildung zusammenhängen.
Als Ergebnis des Vergleichs der Protokolle zwischen Spanien und Deutschland haben sich beide Länder verpflichtet, Richtlinien für die Tuberkulose-Prävention zu erstellen, um die von der WHO vorgeschlagenen Ziele auf globaler Ebene zu erreichen, die sich in der Meldung von Fällen, der Chemoprophylaxe und der Behandlung der latenten Tuberkulose decken. Sie einigen sich auch auf diagnostische Methoden, die darauf abzielen, die Zahl der Fälle zu reduzieren und den Patienten im Falle einer möglichen Infektion zu helfen, auf eine individualisierte Beurteilung und anschließende Nachsorge, um die Diagnose bei Personen zu bestätigen, die aufgrund sozioökonomischer Bedingungen, Obdachlosigkeit, Kindern aus Ländern mit einer hohen Tuberkulose-Inzidenz im Prozess der Adoption oder Migration gefährdet sind. Die beiden Nationen haben gemeinsame Aktionen in der Patientenaufklärung, der Suche nach den besten Behandlungen und der Betreuung von Patienten und ihren Familien durch ein multidisziplinäres

Team, der Ausbildung, der Arbeitsüberlastung und der Art und Weise, wie die Mitarbeiter die entsprechenden Protokolle befolgten.

Unsere Ergebnisse deuten darauf hin, dass zur Senkung der Tuberkulose-Prävalenz und des Tuberkulose-Risikos unter den Arbeitnehmern eine stärkere Einhaltung der Normen für Sicherheit und Gesundheitsschutz am Arbeitsplatz, die Überwachung von Präventivmaßnahmen und mehr Forschung zur Überwachung dieser Maßnahmen erforderlich sind.

Das folgende Kapitel zeigte die Wirksamkeit von Bildungsprogrammen, die sich auf einen technologischen Ansatz konzentrieren. Neue Lehrmethoden, die auf IKT als gemischtes Modell basieren, verbessern die Präventionskultur und das Präventionswissen unter Studenten und zukünftigen Gesundheitsfachleuten. Die Evaluierung der Plattform zeigte, dass die Meinung der Nutzer über die Einbeziehung dieses technologiebasierten Bildungsansatzes zufriedenstellend war. Die anschliessende Analyse des Grundlagenwissens und der Inzidenz biologischer Unfälle hat das Potenzial der Plattform als nützliches und praktisches Präventionsinstrument für die Spezialisierung und der verschiedenen Gesundheitsfachleute aufgezeigt, wie dieser Ansatz auch für ihre Weiterbildung genutzt werden könnte.
Aus den Ergebnissen konnte geschlossen werden, dass es notwendig ist, den Einsatz von IKT im Bereich Gesundheit und Sicherheit am Arbeitsplatz sowie spezifische Protokolle oder technologische Werkzeuge einzubeziehen. Daher war das letzte Kapitel die erste Version einer Plattform: Die Plattform wurde so konzipiert, dass sie verschiedene Segmente umfasst, wie z.B. ein Virtuelles Labor (VL). Diese Plattform hat den Zweck, eine virtuelle Erfahrung des Online-Lernens zu schaffen, um das Wissen über die Risiken der exponierten Arbeitnehmer sowie über die wichtigsten Maßnahmen zur Kontrolle und Prävention der Krankheitserreger zu verbessern. Die Evaluierung der Plattform zeigte, dass die Meinung der Nutzer über die Einbeziehung dieses technologiebasierten Bildungsansatzes zufriedenstellend war. Weitere Analysen des Grundlagenwissens und der Inzidenz von biologischen Unfällen haben das Potenzial der Plattform als nützliches und praktisches Präventionsinstrument für die in den Labors beteiligten Fach- und Berufsgruppen aufgezeigt; sie könnten es auch für ihre Weiterbildung nutzen.
In diesem Sinne scheinen die verschiedenen Bildungsplattformen für die Ausbildung von Jugendlichen, für den Arbeitsplatz und für das Wohlbefinden nützlich zu sein.

Zukünftige Forschungsarbeiten

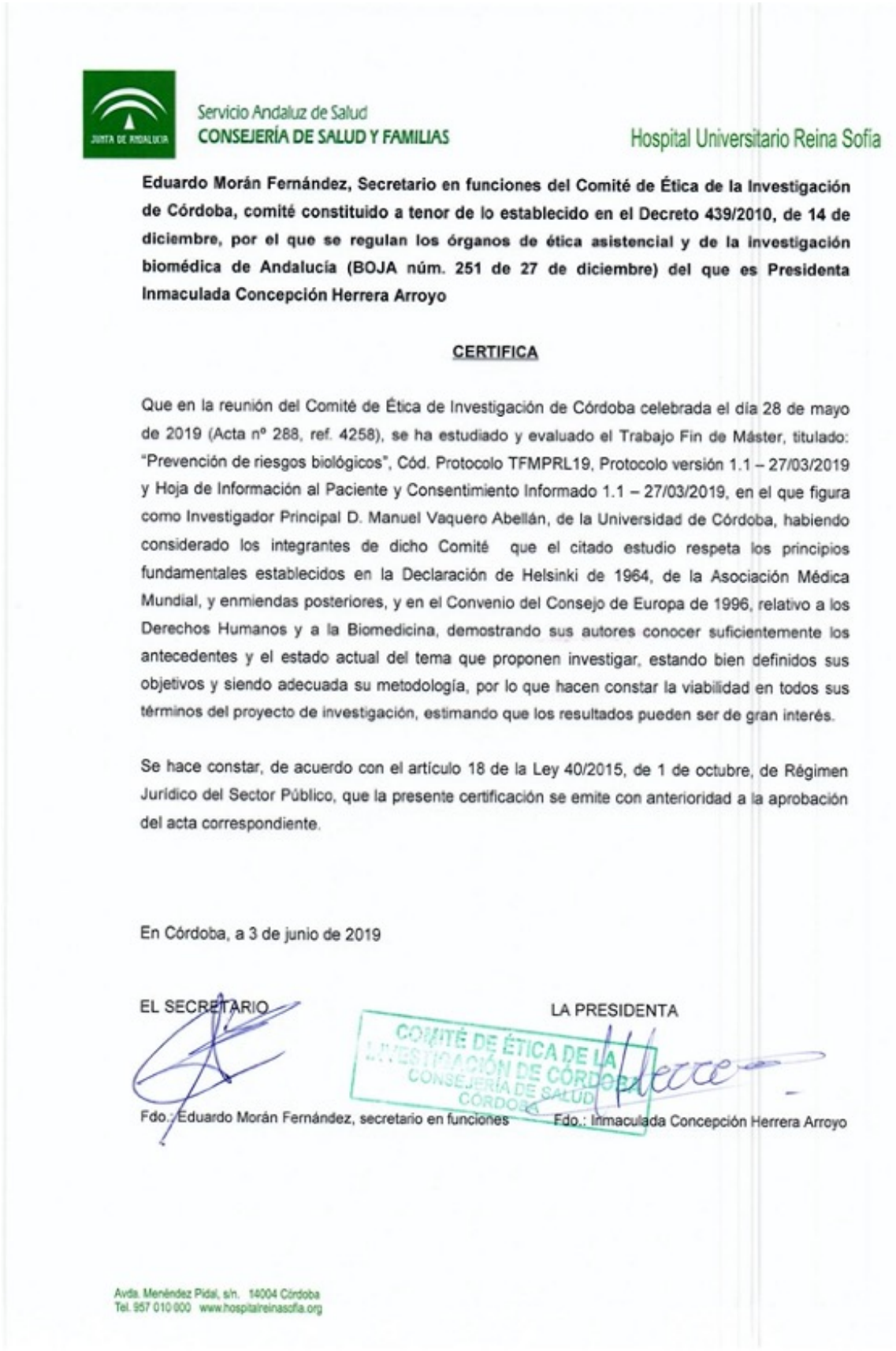
Es sind weitere Arbeiten erforderlich, um den Grad der Einbeziehung oder Nutzung von IKT für Gesundheit und Sicherheit am Arbeitsplatz bei Arbeitnehmern und Gesundheitsorganisationen zu bestimmen. In dieser Hinsicht werden künftige Studien die Forschung über die Wirksamkeit der in Entwicklung befindlichen Plattform zur Verringerung der Risikoexposition und zur Verhütung von Arbeitsunfällen ausweiten. Diese neuen interaktiven Lernmethoden werden ebenfalls erforscht, und es werden verschiedene Richtlinien ausgewählt, die Gamifizierung, virtuelle Realität und künstliche Intelligenz integrieren.

Eines der ursprünglich vorgeschlagenen Ziele in Bezug auf die Messung der Belüftung, die für bestimmte Expositionen in Räumen wie Labors, Primärversorgungssprechstunden oder Notfallzentren erforderlich ist, wird das Thema zukünftiger Forschung sein, da mit der Covid-19-Pandemie die Erfüllung dieses Zwecks eingeschränkt wurde.

Zur Vervollständigung der in der Dissertation vorgeschlagenen Ziele werden schließlich die unveröffentlichten Kapitel überarbeitet und als Papiere oder Konferenzdokumente veröffentlicht.

Annexes

Annexe 1. Ethics Approval from Reina Sofia



Servicio Andaluz de Salud
CONSEJERÍA DE SALUD Y FAMILIAS

Hospital Universitario Reina Sofía

Eduardo Morán Fernández, Secretario en funciones del Comité de Ética de la Investigación de Córdoba, comité constituido a tenor de lo establecido en el Decreto 439/2010, de 14 de diciembre, por el que se regulan los órganos de ética asistencial y de la investigación biomédica de Andalucía (BOJA núm. 251 de 27 de diciembre) del que es Presidenta Inmaculada Concepción Herrera Arroyo

CERTIFICA

Que en la reunión del Comité de Ética de Investigación de Córdoba celebrada el día 28 de mayo de 2019 (Acta nº 288, ref. 4258), se ha estudiado y evaluado el Trabajo Fin de Máster, titulado: "Prevención de riesgos biológicos", Cód. Protocolo TFMPRL19, Protocolo versión 1.1 – 27/03/2019 y Hoja de Información al Paciente y Consentimiento Informado 1.1 – 27/03/2019, en el que figura como Investigador Principal D. Manuel Vaquero Abellán, de la Universidad de Córdoba, habiendo considerado los integrantes de dicho Comité que el citado estudio respeta los principios fundamentales establecidos en la Declaración de Helsinki de 1964, de la Asociación Médica Mundial, y enmiendas posteriores, y en el Convenio del Consejo de Europa de 1996, relativo a los Derechos Humanos y a la Biomedicina, demostrando sus autores conocer suficientemente los antecedentes y el estado actual del tema que proponen investigar, estando bien definidos sus objetivos y siendo adecuada su metodología, por lo que hacen constar la viabilidad en todos sus términos del proyecto de investigación, estimando que los resultados pueden ser de gran interés.

Se hace constar, de acuerdo con el artículo 18 de la Ley 40/2015, de 1 de octubre, de Régimen Jurídico del Sector Público, que la presente certificación se emite con anterioridad a la aprobación del acta correspondiente.

En Córdoba, a 3 de junio de 2019

EL SECRETARIO

LA PRESIDENTA

COMITÉ DE ÉTICA DE LA INVESTIGACIÓN DE CÓRDOBA
CONSEJERÍA DE SALUD
CÓRDOBA

Fdo.: Eduardo Morán Fernández, secretario en funciones

Fdo.: Inmaculada Concepción Herrera Arroyo

Avda. Menéndez Pidal, s/n. 14004 Córdoba
Tel. 957 010 000 www.hospitalreinasofia.org

Annexe 2. Document of the visiting research for the international research

UNIVERSIDAD D CORDOBA

idep

CREDENCIAL DE CONCESIÓN DE AYUDA PARA LA REALIZACIÓN DE ESTANCIAS PARA LA OBTENCIÓN DE LA MENCIÓN INTERNACIONAL EN EL TÍTULO DE DOCTOR

Certificate of funding for research stays in the award of "Doctor International" mention

La Vicerrectora de Posgrado e Innovación Docente de la Universidad de Córdoba, según resolución de 8 de marzo, tiene a bien conceder a **D./Dª. María Esther Vaquero Álvarez**, con documento de identidad número **30994119D**, y matriculado en el **Programa de Doctorado en Biomedicina**, la ayuda establecida por la Universidad de la convocatoria 2018/2019, para realizar una estancia de investigación de 3 meses en **SRH Kliniken Landkreis Sigmaringen. Akademisches Lehrkrankenhaus der Universität Tübingen**, en Sigmaringen (Alemania), por la que recibirá **3300 €** y le posibilitará cumplir los requisitos para la obtención de la Mención Internacional en el Título de Doctor.

The University of Córdoba, as decided is pleased to inform ***Mr./Mrs. María Esther Vaquero Álvarez****, ID number* ***30994119D****, who is enrolled in the* ***doctoral program of Biomedicina****, that he/she has been selected, according to the call 2018/2019, for a 3 months stay fellowship to undertake research at (University/Research Centre)* ***SRH Kliniken Landkreis Sigmaringen. Akademisches Lehrkrankenhaus der Universität Tübingen****, in Sigmaringen (Germany), for which he/she will recibe* ***3300 €****, this binding to award the Doctor International Mention.*

Córdoba, 28 de mayo de 2019

VICERRECTORA DE POSGRADO E INNOVACIÓN DOCENTE
Vice-Rector of Postgraduate and Teaching Innovation

Julieta Mérida García

Código Seguro de Verificación	VLPGLNOMK4X5CXUTCJ4RBMYIXA	Fecha y Hora	03/06/2019 13:52:18
Normativa	Este documento incorpora firma electrónica reconocida de acuerdo a la ley 59/2003, 19 de diciembre, de firma electrónica		
Firmado por	JULIETA MERIDA GARCIA		
Url de verificación	https://sede.uco.es/verifirma/	Página	1/1

Annexe 3. Document of the German supervisor regarding the visiting research

European/International Mention in the Doctorate Degree

Certificate of stay

I hereby confirm that Mr. / Mrs _____**Esther Vaquero Álvarez**_____

has steadily stayed at _____ **Onkologische Institutambulanz SRH Kliniken Landkreis in Sigmaringen, Germany**_____

from _**02**__/__**09**__/__**2019**_ to __**30**__/__**11**__/_**2019**__ and has successfully developed research in _**Health and safety in hospital**

pharmacy and oncology__ that is directly related with his/her PhD thesis in__**Biomedicine**_____.

Signature of the director/responsible of the research group

Institutional Stamp

2.12.19

Dr. Gabriele Käfer
Ärztin
SRH Klinik Sigmaringen
Hohenzollernstr. 40
Tel. 07571 1002743
Fax 07571 1002506

Name : Dr. Med. **Gabriele Käfer**
Leitende Oberärztin Onkologische Institutambulanz
Fachärztin für Innere Medizin, Hämatologie und Internistische Onkologie

Signed in _ Sigmaringen _, _2_ of __December__ , 2019

Annexe 4. Certificate of the Funding from to carry out the visiting research

CONVOCATORIA EXTRAORDINARIA DE AYUDAS PARA LA REALIZACIÓN DE ESTANCIAS PARA LA OBTENCIÓN DE LA MENCIÓN INTERNACIONAL EN EL TÍTULO DE DOCTOR

MEMORIA DEL TRABAJO DESARROLLADO EN EL CENTRO RECEPTOR
(Incluyendo objetivos, metodología y resultados obtenidos)

Nombre y apellidos: Esther Vaquero Álvarez

Introducción

- El conjunto hospitalario SRH Kliniken Sigmaringen, Baden Württemberg, Alemania se compone de tres hospitales comarcales: Sigmaringen, Pfullendorf y Bad Saulgau; y es hospital universitario de la Universidad de Tübingen (Akademisches Lehrkrankenhaus der Universität Tübingen). En él trabajan más de 1400 personas, tiene 532 camas, y son tratados más de 20.000 pacientes anualmente. El hospital en Sigmaringen posee 20 departamentos especializados en diferentes áreas y 10 de ellos están certificados. Asimismo, el hospital es uno de los catorce centros de oncología en Baden-Württemberg y pertenece a uno de los cinco centros universitarios de tumores; todo ello hace posible la atención oncológica integral y de calidad. Los procedimientos y protocolos de oncología están certificados por la Asociación del Cáncer y el Ministerio de Asuntos Sociales de Baden-Württemberg. El departamento de Oncología da servicio al distrito de Sigmaringen y a las regiones circundantes con una población aproximada de 150.000 personas. El tratamiento de pacientes con tumores malignos es uno de los principales servicios ofrecidos por SRH Kliniken Landkreis Sigmaringen GmbH.

- Uno de los requisitos esenciales para el tratamiento óptimo de los pacientes con un tumor diagnosticado es la cooperación interdisciplinaria de los diferentes equipos involucrados (como el servicio de farmacia, medicina interna, oncología, enfermería, oncopsicología). Estos se encuentran certificados individualmente y se agrupan en el Centro de Oncología Sigmaringen. A través de cursos y conferencias semanales sobre tumores, un Registro Clínico de Cáncer, participación del comité de ética, y relación con el Centro de Tumores

1

del Hospital Universitario de Tübingen, así como la colaboración de médicos y grupos de autoayuda establecidos, se asegura que las personas con cáncer sean tratadas de manera integral y al más alto nivel profesional.

- Muchas personas se enfrentan, tras un diagnóstico oncológico, por primera vez a una enfermedad muy grave. La variedad de tratamientos hace indispensable la cooperación de diferentes especialidades e instituciones médicas. El centro de oncología del hospital de Sigmaringen cubre la prevención, detección temprana, diagnóstico, terapia quirúrgica y médica y radioterapia. Además de prestar atención psico-oncológica, cuidado posterior y rehabilitación de los pacientes.

Objetivos

- Conocer el servicio de Oncología del Hospital del Día de Sigmaringen Alemania y su servicio de Farmacia.
- Familiarizarme con medidas de Higiene y Salud Pública.
- Establecer medidas de higiene y actualizar protocolos a nivel de Farmacia Hospitalaria.
- Desarrollar protocolos de quimioterapia, y estudiar la plausibilidad de las terapias y los diagnósticos que los especialistas en oncología determinan.
- Proporcionar información relativa a la quimioterapia tanto al equipo sanitario como al paciente. Educación sanitaria. Atención farmacéutica.

Metodología

- La limpieza ambiental es importante para reducir la contaminación microbiana de las superficies y el riesgo posterior a la transmisión de infecciones asociadas a la atención de la salud. He aplicado protocolos de higiene y limpieza basados en las pautas de la Organización Mundial de la Salud.
- Las pautas de higiene son imprescindibles e incluyen: la limpieza previa, la desinfección para reducir el número de microorganismos patógenos en superficies y objetos; y la

esterilización para inactivar a todos los microorganismos.

- He seguido prácticas para limitar la transmisión potencial de agentes infecciosos a los pacientes en la obtención, almacenamiento y distribución de preparaciones farmacéuticas (Organización Mundial de la Salud. Prevención de las infecciones nosocomiales. Guía práctica. WHO/CDS/CSR/EPH/2002.12 Organización Mundial de la Salud, 2003).
- He aplicado la metodología de estudios epidemiológicos para definir y redactar procedimientos de calidad relacionados con la gestión de ensayos clínicos en los Servicios de Farmacia Hospitalaria (Gómez B, Placeres M, Suñé MP, Mur A, Tordera M, Idoipe A et al. Análisis conjunto y evolución de las actividades farmacéuticas relacionadas con ensayos clínicos en cinco hospitales españoles de tercer nivel. Aten Farm 2009; 11: 287-94.).
- He seguido los principios metodológicos de los Comités de ética asistencial (Sánchez-Caro J, Abellán F. Comités de ética en el ámbito sanitario: clases, competencias y funciones. Informe del experto Nº 17. Fundación Merck Salud. 2018).

Resultados obtenidos

- He dispuesto de la información más reciente sobre desinfectantes, antisépticos y otros agentes antiinfecciosos: propiedades activas en relación con la concentración, temperatura, fecha de vencimiento y espectro de acción; toxicidad e hipersensibilidad/alergia; condiciones físicas con efectos desfavorables en la potencia durante el almacenamiento: temperatura, luz y humedad.
- Destaco mi contribución a la realización semanal de medidas de control higiénico: posible crecimiento de microorganismos, presencia de partículas de forma activa y pasiva (medida de partículas / gérmenes en el aire y placas de agar en contacto con la superficie, respectivamente). Cuando se produce crecimiento, se toman medidas oportunas para combatir al microorganismo causante de la formación de colonias.
- Al trabajar en las salas limpias como farmacéutica, he determinado protocolos de higiene y limpieza de las mismas para un correcto funcionamiento oncología - farmacia.
- He intervenido en las prácticas de esterilización y desinfección del hospital mediante: participación en la formulación de pautas de fabricación de antisépticos, desinfectantes y

productos empleados para el lavado y la desinfección de las manos; formulando pautas para la reutilización de equipos y de materiales para pacientes.

- He participado en el control de calidad de las técnicas empleadas para esterilizar en el hospital, incluida la selección del equipo de esterilización y vigilancia epidemiológica.
- He realizado nuevos protocolos de administración de quimioterapia, en colaboración con médicos y enfermeros.
- En estos meses, he podido valorar aún más la importancia de un equipo multidisciplinar médico - farmacéutico - enfermero - psicooncólogo- paciente.
- He participado en ensayos clínicos que se llevan a cabo actualmente en el centro hospitalario de Sigmaringen.
- Asimismo, he trabajado y contribuido a la mejora del manual de gestión de calidad tanto del servicio de Farmacia como de Oncología.
- He formado parte del comité de ética durante los meses que duró la estancia.
- Esta experiencia me ha ayudado como profesional sanitaria a progresar en muchos aspectos y aprender en otro país a desenvolverme como farmacéutica y estudiante de doctorado. Estar en el extranjero y mejorar el conocimiento del idioma y cultura alemanes ha sido una vivencia que, sin duda, volvería a repetir.

En Córdoba, a 3 de diciembre de 2019

Firma del Doctorando

Esther V A

Fdo.: Esther Vaquero Álvarez

V° B° del Director de la Tesis

Supervisado por: Dra María Dolores Redel Macías

Annexe 5. Certificate of participation in international conferences

change in tuberculin diagnostic preparation. Polish tuberculin, used for many years, was replaced by the Czech tuberculin, with similar power but with different injection volumes. There was also a change in the frequency of field tests performed. Decision of the Chief Veterinary Officer shall be tested annually 20% of the cattle in the area so that within 5 years the entire population was examined. In laboratory test the negative rate (without isolation of strain) ranged from 40 to 50%. This indicates a significant proportion of false-positive results ascertained tuberculin test.
Taking into account all the data obtained during the period, it is clear that testing for bovine tuberculosis in Poland and the adopted system allows to maintain the achieved status of a bovine tuberculosis-free and allows for controlled combat and further elimination of the disease in cattle herds.

P106

TRAINING IN BIOSAFETY AGAINST *M. TUBERCULOSIS*: EXPERIENCE IN THE MYCOBACTERIA REFERENCE CENTER AT THE UNIVERSITY OF CORDOBA, SPAIN

Vaquero-Alvarez Esther, Pablo López-Roldan, Emilio J Aguilar, Fernando Palomares, Francisco Torralbo, Manuel Vaquero, Manuel J Casal
University of Cordoba, Cordoba, Spain

The Mycobacterium Reference Center is a laboratory with a large workload that performs diverse activities like direct sputum smear microscopy, preparation of specimens for use in an automated nucleic acid amplification test cartridge, processing of specimens for inoculation on primary culture media, culture manipulation for identification, DST or line-probe assays on cultured isolates.
Objective: To present our experience in providing information and training our staff to prevent occupational hazards in working with exposure to *M. tuberculosis*.
Methodology: Following a risk assessment is directed a training plan integrated into the Centre prevention plan, where the workers, the head of the laboratory and safety technicians are involved. There are training courses in first aid, fire protection and other specific about biosafety. These courses of 5 hours are taught by specialists in occupational safety. A safety data sheet management of M tuberculosis in the laboratory must be completed and also hazardous waste management must be reported. From existing working procedures in the laboratory, each task is added in a section of safe practices. Finally, we train the personnel coping emergencies as well as a drill for training is carried out.
Results: The course, which is celebrated periodically and attended by all the laboratory personnel, includes training in biosafety concepts on biological agents, classification, transmission, universal measures, biocontainment levels, protective equipment and hazardous waste management.
Our proposed security sheet against M tuberculosis consists of the following sections: description, feasibility, risks in the laboratory, health surveillance, exposure control (containment level, collective and individual protection), handling and storage.
Amongst the several tasks performed by our staff listed in manual work procedures are established biosafety schemes which involve safe practices, use of protective equipment and action to incidents / accidents. There is an outline of the procedure for hazardous waste management.
The staff is trained regularly establishing a simulation to carry out the emergency plan in the laboratory.
Conclusions: Staff training is essential to prevent laboratory-acquired infections, incidents and accidents. This one must include information on safety practices that should be followed to avoid or minimize the risk of inhalation and inoculation and properly decontaminate and also remove infected material.

P110

A NOVEL MODEL TO CONTROL FOR PATIENT RISK FACTORS IN MEASURING THE TRANSMISSIBILITY OF *MYCOBACTERIUM TUBERCULOSIS* STRAINS AND LINEAGES

Hanna Nebenzahl-Guimaraes[1], Martien Borgdorff[2], Jessica de Beer[1], Megan Murray[3], Dick van Soolingen[1]
[1]Rijksinstituut Voor Volksgezondheid En Milieu (Rivm), Bilthoven, Netherlands
[2]Municipal Health Service, Amsterdam, Netherlands
[3]Harvard School of Public Health (Hsph), Boston, USA

Background: Host-related risk factors, such as age, sex and smear positivity, are still considered the most important factors influencing transmission of *Mycobacterium tuberculosis* (MTB). Recent findings however suggest that the spread of MTB also depends on bacteriological factors. So far studies looking at the association between strains or phylogenetic lineages of MTB and transmissibility have arrived at differing and often contradictory conclusions. In the Netherlands all MTB isolates have been subjected to DNA fingerprinting since 1993 and all patient information is available. Here we describe a method for quantifying and controlling for host-related risk factors in order to go beyond the conventional use of cluster size and proportion of cases in a cluster as proxy measures of transmissibility, thus strengthening the association found with strains and phylogenetic lineage.
Methods: Using spoligotyping and MIRU-typing we classified MTB isolates from a nationwide database

34th Annual Congress of the European Society of Mycobacteriology

ESM

30th June – 03rd July 2013
Florence, Italy

Scientific Program including Abstracts

P198

APPS: AN USEFUL TOOL IN THE FORMATION OF PROFESSIONAL EXPOSED TO *MYCOBACTERIUM TUBERCULOSIS* IN THE WORKPLACE

Esther Vaquero-Alvarez[1], José Checa-Claudel[1], Pablo López-Roldán[1], Manuel J Casal[1]
University of Cordoba, Spain

To the World Health Organization, Mycobacterium tuberculosis should be considered among the microorganisms that require Biosafety Level 3, as being a respiratory transmission agent which can cause a serious infection.

As exposure to Mycobacterium tuberculosis, it should be understood the presence of this in the workplace; it can be distinguished into the following two categories: i) those arising from a work activity with an intention to use or to manipulate a biological agent, which is the main purpose of the work (diagnostic microbiological laboratories, as main activity working with biological agents), and ii) that arising from work activity, which does not involve manipulation or work indirect contact or deliberate use of biological agents (exposure incidental to the main purpose of the work).

The use of new technologies to supplement the training of workers has shown to be useful, allowing querying, transmitting specific information and making decisions based on the best available scientific evidence.

Objective: To design an electronic system / digital knowledge, informing workers exposed to M. tuberculosis about the health risks and key control measures and prevention.

Methodology: Developing a Hosted Web App with the aim of disseminating knowledge in the broader spectrum of customers, i.e. computers with OS Windows, Linux and / or Mac OS to support the WEB-date navigation and mobile devices based on Android, iOS and / or FireFoxOS. The completion of the software is based on HTML5, Javascript and CCS, as the current development trend of adaptive applications. Hosted Web App is a reporting system based on WEB and encapsulated for mobile devices. These rely on globalizing the distribution of information.

Results: The application includes: Mycobacteriology laboratory simulation. Photo-gallery and specific information. Video tutorials that show and explain situations of risk exposure in handling these major biological agents, prevention and control. Tutorial which provides technical and legislative information on biological risk by M. tuberculosis, microbiological laboratory techniques, biosafety levels and regulations. Intuitive interface with the proposal of understanding and make information more flexible and accessible for the users.

P207

SPECIES OF MYCOBACTERIA ISOLATED FROM RESPIRATORY SPECIMENS IN SERBIA

Irena Zivanovic[1], Ivana Dakic[1], Dragana Vukovic[1], Gordana Stefanovic[2], Ljiljana Tomic[2], Branislava Savic[1]
[1] Institute of Microbiology and Immunology, Faculty of Medicine, University of Belgrade, Belgrade, Serbia
[2] Laboratory for Mycobacteria, Department of Clinical Microbiology, Clinical Centre of Serbia

Prior to introduction of the molecular tests for identification of species of mycobacteria into the tuberculosis (TB) laboratory network in Serbia, differentiation of *Mycobacterium tuberculosis* complex (MTBC) species was not performed, while majority of isolates of nontuberculous mycobacteria (NTM) were recognized as *Mycobacterium* sp. only. We used the GenoType MTBC and CM/AS assays (Hain Lifescience GmbH, Nehren, Germany) to identify all mycobacterial cultures isolated from respiratory specimens, one culture per patient, in Serbia over a 12-month period, and provided the first comprehensive insight into the local pattern of mycobacterial isolation. The number of patients with pulmonary specimens yielding a positive mycobacterial culture in Serbia from December 1st, 2010 through November 30th, 2011 was 1131. Out of 1131 cultures, 35 were excluded due to contamination, while the remaining 1096 cultures were tested by the GenoType MTBC assay and 971 were identified as *M. tuberculosis* species. No other species of the MTBC was detected in the sample analyzed. The remaining 125 isolates were tested by the CM and AS assays and 123 were identified as NTM. Identification to the species level was achieved in 86 isolates, 37 cultures were identified as *Mycobacterium* sp., while for two strains identification as mycobacterial species failed. In total, NTM isolates accounted for 11.2% of all isolates of mycobacteria identified in pulmonary specimens. The most frequent NTM species was *M. xenopi* (32 out of 86; 37.2%), followed by *M. peregrinum* (12.8%), *M. gordonae* (11.6%), *M. avium* (8.1%), *M. chelonae* (8.1%), *M. intracellulare* (7%), *M. fortuitum* (4.7%); *M. kansasii* (4.7%); *M. abscessus* (3.5%), and *M. scrofulaceum* (2.3%). As expected, *M. tuberculosis* is by far the most important mycobacterial species in Serbia. As far as pattern of isolation of NTM is concerned, frequent occurrence of *M. peregrinum* in respiratory specimens was a somewhat surprising finding, and may indicate presence of specific environmental sources of this bacterium. Low frequency of *M. avium* was also noteworthy, since it is among the most frequently identified NTM in respiratory specimens from different parts of the world. The results obtained should lead to rational and cost-efficient application of the GenoType assays in routine laboratory diagnostics of mycobacterial infections in Serbia. Our results suggest that rapid identification that distinguishes MTBC from NTM as well as speciation of NTM isolates are required while identification at the species/subspecies level of the MTBC isolates is not necessary in routine diagnostic algorithm of TB.

P241

OCCURENCE OF RPOB MUTATIONS IN GERMAN INH RESISTANT BUT RMP SUSCEPTIBLE *M. TUBERCULOSIS* ISOLATES

Andrea Sönke[1], Doris Hillemann[2], Sabine Rüsch-Gerdes[1], Elvira Richter[1]
[1] Research Center Borstel, National Reference Center for Mycobacteria, Borstel, Germany
[2] Research Center Borstel, Germany

Mycobacterium tuberculosis isolates that harbor *rpoB* mutations within the rifampicin (RMP) resistant determining region (RRDR) and test RMP susceptible by phenotypical drug susceptibility testing (DST) methods limit the reliability of the results obtained from molecular assays. We aimed to investigate the presence of *rpoB* mutations in phenotypically isoniazid (INH) resistant/RMP susceptible strains that were isolated from patients in Germany to analyze the frequency of this constellation and to evaluate the RMP susceptibility with different DST methods.

In total 143 INH resistant and RMP susceptible *M. tuberculosis* isolates submitted to the German National Reference Laboratory for Mycobacteria, Borstel in 2011 were analyzed in this study. Sequencing of the *rpoB*-RRDR, of *katG* and of the *inhA* ribosome binding site was performed. RMP minimal inhibitory concentrations (MIC) were determined by two methods, the BACTEC 960 Mycobacteria Growth Indicator Tube (MGIT) system and by the proportion method on Löwenstein Jensen (LJ) medium.

139 of the 143 strains showed no mutation while four strains (2.8%) had at least one *rpoB* mutation in the RRDR. Two of the four strains had the mutation L533P. The other two strains had a mutation D516Y in combination with a second mutation within the RRDR (N518D and E510H). Analysis of the RMP MIC values below the standard critical concentrations revealed different MICs for the four strains. The MIC values ranged from 1.25 to 40 µg/ml on LJ and from 0.25 to 1 µg/ml for BACTEC MGIT 960. One strain had MIC values close to the critical concentrations which could be shown by both methods. In addition 8 of the 139 strains with a *rpoB* wildtype were tested and growth of all 8 strains was inhibited at 0.25 µg/ml (MGIT 960) and 2.5 µg/ml (LJ).

INH resistant/RMP susceptible strains represent the main source for the development of multidrug resistant strains. Here we describe the presence of *rpoB* mutations under debate in four RMP phenotypic susceptible strains. Three of the four strains showed slightly elevated MICs but below the critical concentration while one strain showed no elevated MIC when performing DST on BACTEC MGIT 960 or the proportion method on LJ. We conclude from these data that both methods are equally reliable for phenotypic DST and MIC determination.

P220

CLINICAL SIGNIFICANCE OF SPECIMENS WITH POSITIVE RESULTS BY PCR AND NEGATIVE CULTURE FOR ROUTINE DETECTION OF *MYCOBACTERIUM TUBERCULOSIS* COMPLEX

Juana Cacho[1], Miriam Fuentes[1], Jesús Martínez Carrillero[1], Sergio Rodríguez[1], Working Group of Tuberculosis Unit Area 10[2]
[1]Servicio de Microbiología, Hospital Universitario de Getafe, Madrid, Spain
[2]Servicio de Medicina Interna, Hospital Universitario de Getafe, Madrid, Spain

Introduction

The rapid diagnosis is essential in control of tuberculosis (TB). Several commercial direct nucleic-acid amplification tests (NAATS) have been developed to allow rapid detection of mycobacteria in pulmonary and extrapulmonary specimens.

Objects

The study describes clinical evaluation of the samples with positive results by NAATS and negative culture for routine detection of *Mycobacterium tuberculosis* complex (MTC).

Methods

A total of 31 specimens (13 respiratory and 18 non respiratory) from 29 patients were selected from 8746 samples processed in our Mycobacterial Laboratory between 2009 and 2013.

The selection criteria of the samples were all specimens that were culture negative for MTC but positive by PCR. Then we carried out the clinical evaluation of the patients according to the patient's clinical history provided evidence of TB sufficient to initiate antituberculous therapy.

All samples, except those that came from sterile compartments, were decontaminated by the NALC/NaOH 1% method and concentrated by centrifugation. Decontaminated samples were used to prepare a smear for microscopic examination (fluorochrome staining) and inoculated into liquid media (BACTEC MGIT 960 system; Becton Dickinson, USA).

Commercial NAATs used for study period were COBAS TaqMan MTB (Roche Molecular Systems, Switzeland), GenoType ® MTBDRplus (Hain Lifescience, Germany) and Xpert® MTB/RIF (Cepheid, CA), they were introduced step by step into the laboratory procedures.

Results

A total of 24 (82.8%) of 29 patients had definite TB, 9 (37.5%) pulmonary TB and 15 (62.5%) had extrapulmonary TB.

From a total of 31 specimens, 13 (42%) were

35th Annual Congress of the European Society of Mycobacteriology

ESM

29th June – 02nd July 2014
Vienna, Austria

Scientific Program including Abstracts

LIST OF POSTER PRESENTATIONS (P)

CHANCES AND CHALLENGES OF RAPID DIAGNOSTICS

P21
EVALUATION OF GENEXPERT MTB/RIF ASSAY FOR THE DIAGNOSIS OF TUBERCULOSIS AND RAPID DETECTION OF RIFAMPIN RESISTANCE IN CLINICAL SPECIMENS
Cengiz Cavusoglu, Mehmet Soylu

P68
HIGH RESOLUTION MELTING CURVE ANALYSIS FOR DETECTION OF MUTATION IN PNCA GENE
M.A. Dymova, E.A. Khrapov, Maxim Filipenko

P101
EVALUATION OF THE NEW COMMERCIAL ASSAY SPEED-OLIGO® MYCOBACTERIA FOR THE IDENTIFICATION OF NONTUBERCULOUS MYCOBACTERIA
Ivy Bastos Ramis, Margo Cnockaert, Anne Simon, Juan Carlos Palomino, Pedro Eduardo Almeida da Silva, Peter Vandamme, Emmanuel Andre, Anandi Martin

P108
ISONIAZID MINIMAL INHIBITORY CONCENTRATIONS FOR *MYCOBACTERIUM TUBERCULOSIS* WITH KAG MUTATION IN THE THORAX CENTRE HECKESHORN, BERLIN
Ralf Otto-Knapp, Nicolas Schönfeld, Lena Bös, Gudrun Bettermann, Andreas Roth, Timo Weiß, Silvan Vesenbeckh, Holger Rüsamann, Harald Mauch, Torsten T. Bauer

P126
RELOCATION OF A MYCOBACTERIAL DIAGNOSTIC LABORATORY: ADDRESSING OPERATIONAL AND BIOSAFETY CHALLENGES
Justins Peh, Melody TL Kee, Helen Hla Hla Htay, Siaw Eng Ho, Kee Mong Ha, Lynn MY Choy, Maria DG Quieng, Benjamin WM Lee, James Sim, Li-Hwei Sng

P138
HOW SAFE ARE SOME OF THE COMMON PRACTICES IN MYCOBACTERIOLOGY LABORATORIES?
Leen Rigouts, Fissette Klista, Bombeeck Deirdre, Mulders Wim, de Jong Bouke

P149
ASSESSMENT OF THE BD MGIT TBC IDENTIFICATION TEST FOR THE DETECTION OF *MYCOBACTERIUM TUBERCULOSIS* COMPLEX IN A NETWORK OF MYCOBACTERIOLOGY LABORATORIES
Diana Machado, Jorge Ramos, Isabel Couto, Nureisha Cadir, Inácio Narciso, Elizabeth Coelho, Sofia Viegas, Miguel Viveiros

P153
EVALUATION OF ANYPLEXTMPLUS MTB/NTM DETECTION IN RESPIRATORY SAMPLES
Ariadna Rando, Elena Quintana, Maria Teresa Tortola Fernandez

P178
EVALUATION OF THE PROPIDIUM MONOAZIDE VIABILITY ASSAY AS A NOVEL BIOMARKER FOR TUBERCULOSIS TREATMENT MONITORING VIA MOLECULAR APPROACHES
Ecita Pimkina, Jovile Raudoniute, Paolo Miotto, Vlad Nikolayevskyy, Francis Drobniewski, Irina Kontsevaya, Olga Ignatyeva, Anna Isaeva, Alexandr Kovalyov, Svetlana Mironova

P198
APPS: AN USEFUL TOOL IN THE FORMATION OF PROFESSIONAL EXPOSED TO *MYCOBACTERIUM TUBERCULOSIS* IN THE WORKPLACE
Esther Vaquero-Alvarez, José Checa-Claudel, Pablo López-Roldán, Manuel J Casal

P207
SPECIES OF MYCOBACTERIA ISOLATED FROM RESPIRATORY SPECIMENS IN SERBIA
Irena Zivanovic, Ivana Dakic, Dragana Vukovic, Gordana Stefanovic, Ljiljana Tomic, Branislava Savic

P214
OCCURENCE OF RPOB MUTATIONS IN GERMAN INH RESISTANT BUT RMP SUSCEPTIBLE *M. TUBERCULOSIS* ISOLATES
Andres Sönke, Doris Hillemann, Sabine Rüsch-Gerdes, Elvira Richter

P220
CLINICAL SIGNIFICANCE OF SPECIMENS WITH POSITIVE RESULTS BY PCR AND NEGATIVE CULTURE FOR ROUTINE DETECTION OF *MYCOBACTERIUM TUBERCULOSIS* COMPLEX
Juana Cacho, Miriam Fuentes, Jesús Martínez Carrilero, Sergio Rodriguez, Working Group of Tuberculosis Unit Area 10

P221
DEVELOPMENT OF MULTIPLEX REAL-TIME PCR KIT FOR DETECTION AND DIFFERENTIATION OF MEMBERS OF THE *MYCOBACTERIUM TUBERCULOSIS* COMPLEX IN CLINICAL SPECIMENS
Maria Alvarez Figueroa, Ekaterina Dolgova, Diana Levi, Anastasiya Prokopenko, Tatyana Sevastyanova

P223
THE EXPERIENCE OF CLUJ NAPOCA LABORATORY IN SCALING UP THE RAPID DIAGNOSIS OF DRUG RESISTANT TUBERCULOSIS
Daniela Homorodean, Jodal Andrea Melinda

P246
DETECTION OF ISONIAZID-RESISTANT *MYCOBACTERIUM TUBERCULOSIS* BY PADLOCK PROBES COMBINED WITH LATERAL FLOW NUCLEIC ACID BIOSENSOR
Pavankumar Asalapuram, Anna Engström, Jie Liu, Mats Nilsson

La Comunicación Oral

CREACIÓN DE UNA WEB MÓVIL: "PORTAL SANITARIO PARA LA FORMACION E INFORMACIÓN DE LOS PROFESIONAL EN EL ÁMBITO SANITARIO: PSAM"

de la que son autores

P. Aparicio-Martínez, E. Vaquero Álvarez, M.P. Martínez-Jiménez, y M. Vaquero Abellan

ha sido presentada en el marco del
V Congreso Internacional de Salud Laboral y Prevención de Riesgos
celebrado en Madrid del 8 al 10 de junio de 2017,
lo que se certifica a los efectos oportunos

Benilde Serrano Saiz
Presidenta del Congreso
Madrid, 10 de junio de 2017

Sociedad Castellana de Medicina y Seguridad del Trabajo
www.semst.es

ICMMI 2018 *2018 IERI International Conference on Medical Physics,Medical Engineering and Informatics (ICMMI 2018),September 7-9, 2018, Macau*

May 12, 2018

Dear PILAR APARICIO-MARTINEZ, MARIA DEL PILAR MARTINEZ-JIMENEZ, ALBERTO-JESUS PEREA-MORENO, ESTHER VAQUERO-ALVAREZ, MARIA DOLORES REDEL-MACIAS, MANUEL VAQUERO-ABELLAN

We are pleased to inform you that your abstract submission has been accepted for oral presentation at 2018 IERI International Conference on Medical Physics, Medical Engineering and Informatics (ICMMI 2018) to be held on September 7-9, 2018, at Macau, Special Administrative Region of the People's Republic of China. (http://www.icmmi-conf.com/).

Paper ID#: E135
Paper Title: A mobile interactive health application for biological risk prevention in coming hazardous actions: PSAM
Authors: PILAR APARICIO-MARTINEZ, MARIA DEL PILAR MARTINEZ-JIMENEZ, ALBERTO-JESUS PEREA-MORENO, ESTHER VAQUERO-ALVAREZ, MARIA DOLORES REDEL-MACIAS, MANUEL VAQUERO-ABELLAN

The acceptance decision is based on peer-reviews conducted by conference chairs and assigned reviewers from the scientific committee.[For inclusion in the ICMMI 2018 Conference Proceedings and program, at least one unique registration per paper is required].

Your abstract will be published on the Journal Basic & Clinical Pharmacology & Toxicology (ISSN: 1742-7843), which will be indexed by **Science Citation Index (SCI) and Science Citation Index Expanded (SCIE)**. Please return the registration form, scanned payment proof and final abstract to icmmi2018@aerproceedings.org before May 20, 2018

We look forward to seeing you in Macau!
Sincerely,

Harry Zhang

Registration No 201116767W

Program Chair of ICMMI 2018
Harry Zhang, Singapore Management and Sports Science Institute, Singapore

Certificate of Presentation

this is to certify that the abstract entitled

'Management of hazardous infectious waste in a Mycobacteria reference center'

by the below authors

E Vaquero-Alvarez, E Aguilar, A Gomera
P Ruiz-Martinez, A deToro, C Guijarro
M Casal

Valencia (SPAIN) 30 June - 3 July 2019

EUROPEAN SOCIETY OF MYCOBACTERIOLOGY

Daniela Maria Cirillo, ESM President
on behalf of the ESM Board

Certificate of Presentation

this is to certify that the abstract entitled

'Proposal for control of ventilation with low-cost sensors that use a standardized and open data management model based on the European FiWare standard'

by the below authors

E Vaquero-Alvarez, J Checa-Claudel

Valencia (SPAIN) 30 June - 3 July 2019

EUROPEAN SOCIETY OF MYCOBACTERIOLOGY

Daniela Maria Cirillo, ESM President
on behalf of the ESM Board

P22. New methodologies for preventing exposure to biological agents in the labs

Authors: Esther Vaquero Álvarez, Pilar Aparicio Martínez, María del Pilar Martínez Jiménez
Affiliations: [1]Postgraduate Student University of Córdoba, SPAIN. [2]Research Group, epidemiology reserch in Primary care (GC-12) from Instituto Maimónides de Investigación Biomédica de Córdoba (IMIBIC), SPAIN. [3]Dep. Applied Physics, Albert Einstein Building, Rabanales Campus, Universidad de Cordoba (SPAIN).
Scientific Program: Infectious and Immunological diseases.
Keywords: Biological agents, e-learning, new technologies, medical informatics.

Abstract:
The exposure to biological and chemical agents in laboratory is warning problem for the workers. In laboratories focused on samples, the most problem is the exposure to biological agents that can produce different sides effects especially health issues. In this sense, the practice and experience of workers play an important role in preventing accidents and correctly following the protocols for post-exposure. Based on the previous state, the practice in laboratories is essential for the learning process and correct performance. Furthermore, the rapid development of new communication technologies has allowed to improve the training by using online or in distance technologies such as virtual laboratories. The objective of this research is to present and demonstrate the importance of this technologies for workers in contact with biological agents. This research presents three online technologies based on HTML5 and MSyQL in order to improve the learning process of the employees from workers of the lab, nurses that obtained the samples and students. The first platform is called Forsan (http://www.uco.es/investiga/grupos/LVRiesgosLaborales/formacion-sanitaria/animaciones), in which are included different tools to inform and form students. The second platform is named Psam (http://www.uco.es/psam/rpsindice.php) focused on forming health professionals that may in contact with the origin of biological agents. Finally, the last platform is called Bioslab (http://www.uco.es/RiesgosLaborales/sanitario/), which is focused on prevention on the laboratories. Additionally, these virtual platforms were evaluated by different health professionals and laboratories' labs (N=27) defined these technologies as "good" and "useful" and given a 5.6 punctuation out of 7 in scale of resourcefulness. In conclusion, these technologies provide a methodology of improve for any worker or student and has been highly valuated by the users.

10TH IMIBIC YOUNG INVESTIGATORS MEETING

IMIBIC BUILDING
CONFERENCE ROOM
CÓRDOBA, 16-17 MAY, 2019

ABSTRACT BOOK

Annexe 6. Certificate of publication the papers

International Journal of
Environmental Research and Public Health

MDPI

Article

Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], Pilar Ruiz-Martínez [3], Manuel Vaquero-Abellán [4,5], María Dolores Redel Mecías [2] and Pilar Aparicio-Martínez [4,5,*]

1 SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de
2 Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C.-A.); ig1remam@uco.es (M.D.R.M.)
3 GC24 Clinical and Molecular Microbiology, Instituto Maimónides, Facultad Medicina y Enfermería, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; mi1rumap@uco.es
4 GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; en1vaabm@uco.es
5 Departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, 14071 Córdoba, Spain
* Correspondence: n32apmap@uco.es; Tel.: +34-679-727-823

Received: 16 August 2020; Accepted: 13 September 2020; Published: 16 September 2020

check for updates

Abstract: Since the eighties, technological tools have modified how people interact in their environment. At the same time, occupational safety and health measures have been widely applied. The European Agency for Safety and Health at Work considers that information and communication technologies are the main methods to achieve the goals proposed to improve working life and the dissemination of good practices. The principal objective was to determine the trends of publications focused on these technologies and occupational safety in the healthcare sector during the last 30 years. A bibliometric study was carried out. The 1021 documents showed an increased trend per country, especially for the United States ($p < 0.001$) and year ($p < 0.001$). The citations per year showed significant differences between citations of articles published before 2007 ($p < 0.001$). The year was also linked to the increase or decrease of articles (72.2%) and reviews (14.9%) ($p < 0.001$). The analysis of journal co-citations also showed that the main journals (such as Infection Control and Hospital Epidemiology) were linked to other important journals and had a major part in the clusters formed. All these findings were discussed in the manuscript and conclusions were drawn.

Keywords: healthcare workers; ICTs; occupational health; scientometric analysis

1. Introduction

Since the eighties, technological tools have modified how people interact with their environment [1]. At the same time, occupational safety and health (OSH) measures were widely applied due to the recommendation of the World Health Organization (WHO) regarding the health and working environment [2]. Both changes facilitated the inclusion of information and communication technologies (ICTs) in the working environment [3]. Numerous countries, such as the United States (US) or the United Kingdom (UK), included information and communication technologies (ICTs) in several structures from industries to healthcare systems for workers and consumers [4–6].

Following the technological growth in the last decade, multiple ICTs, digital and analog substructure, gears, and widgets [7] have been created to improve the health of the populations and

control risks in the environment [8,9]. In this sense, one of the main points for creating ICTs has been the development of different structures to improve the accessibility and sharing of information [9–11]. Among these new technologies, smartphones, computers, or tablets have become the favorite tools to access or exchange information [12–14]. This preference is based on their ubiquitous, easy-to-use nature and fast features [15]. Nevertheless, the use of ICTs in the workplace could be described as both favorable and unfavorable. Positively, when robotics and other technological advances are effectively used, hazards can be reduced, and training can improve [16]. However, when these technologies are misused, these tools can introduce new dangers and impact the psychosocial health of workers [17,18]. In this sense, several studies have analyzed the influence of ICTs on workers' health, highlighting mental stress or burnout syndrome, muscular problems and audio-visual alterations, and even addiction [19,20]. Nevertheless, the impact that technology has in any area is partially determined by the creator's desire or intention, and the impact of ICT depends on the user's profile and reason for utilizing such technology [21].

Despite the negative effect, European organizations, especially the European Agency for Safety and Health at Work, consider that ICTs are the primary method to achieve the goals proposed to improve working life and disseminate good practices [16]. Nevertheless, the different analyses indicated that the ICTs were not entirely integrated into occupational health and that depending on the sector, the actions of the OSH focused on one area [22,23]. An example would be that financial and scientific sectors focused on psychosocial prevention and health promotion activities, in which ICTs focused on control or training, mainly in industrial environments [24,25]. Meanwhile, the social and health sector was also more likely to promote health in the workplace, with a particular interest in promoting healthy lifestyles [22]. These results are highly contradictory since the health sector workers are more exposed to psychosocial problems, such as burnout syndrome, musculoskeletal disorders, and biological accidents [26–29]. Different reviews have shown how ICTs, especially websites or databases, could decrease these risks and promote a healthier working environment [30,31]. However, it seems that the latest ICTs created mainly focused on improving structures, surgical approaches, or treatments for patients [32,33]. Even though healthcare workers are at high risk of suffering from a disease or accident, their working environment is up against constant changes and depends on the needs of the population [31,34]. The ICTs could be applied to increase prevention knowledge and skills, changing the environment to improve workers' well-being and optimize prevention through adequate human and material resources [35]. In fact, previous studies have stated different benefits of ICTs in the occupational health in healthcare sector from continuous training to productivity improvements [36,37]. The most outstanding benefits have been increasing efficiency, reducing errors and improving integration of best practice into routine care [36]. Currently, the ICTs in OHS seem to focus on improving clinical information systems, personal digital assistants or keeping health records of personnel [38]. Nevertheless, the analysis of previous works as a vital step in research is essential [39,40]; therefore, it is imperative to determine the previous knowledge and current tendencies in this scientific field.

Based on this, the principal objective of the current study was to determine the trends of publications focused on ICTs and occupational safety and health in the healthcare sector during the last 30 years (from 1989 to 2019). Additionally, the second objective was to determine the major sub-topics regarding the use of ICTs in occupational safety in the healthcare sector. The purpose of these objectives was to understand ICTs and OSH's interaction better to assist the decision-making of health professionals and contribute to effective prevention.

69. Sathish, M.; Eswar, R. Systematic reviews and meta-analysis in spine surgery—How good are they in methodological quality? A systematic review. *Glob. Spine J.* **2020**. [CrossRef]
70. Fiabane, E.; Giorgi, I.; Sguazzin, C.; Argentero, P. Work engagement and occupational stress in nurses and other healthcare workers: The role of organisational and personal factors. *J. Clin. Nurs.* **2013**, *22*, 2614–2624. [CrossRef]
71. Bahn, S.; Barratt-Pugh, L. Emerging issues of health and safety training delivery in Australia: Quality and transferability. *Procedia Soc. Behav. Sci.* **2012**, *62*, 213–222. [CrossRef]
72. de Carvalho, D.C.; da Rocha, J.C.; de Gimenes, M.C.A.; Santos, E.C.; Valim, M.D. Work incidents with biological material in the nursing team of a hospital in Mid-Western Brazil. *Esc. Anna Nery* **2017**, *22*. [CrossRef]
73. Pascoe, M.; Alberts, J.; Wang, L.; Bruton, M.; Rogen, B.; Rehm, S.J.; McHugh, L.; Katzan, I.; Foldvary-Schaefer, N. Feasibility of electronic sleep disorder screening in healthcare workers of a large healthcare system. *Sleep Med.* **2020**, *73*, 181–186. [CrossRef]
74. Sheraton, M.; Deo, N.; Dutt, T.; Surani, S.; Hall-Flavin, D.; Kashyap, R. Psychological effects of the COVID 19 pandemic on healthcare workers globally: A systematic review. *Psychiatry Res.* **2020**, *292*, 113360. [CrossRef]
75. Pikkarainen, M.; Pekkarinen, S.; Koivumäki, T.; Huhtala, T. Data as a driver for shaping the practices of a preventive healthcare service delivery network. *J. Innov. Manag.* **2018**, *6*, 55–79. [CrossRef]
76. Flores, M.; Glusman, G.; Brogaard, K.; Price, N.D.; Hood, L. P4 medicine: How systems medicine will transform the healthcare sector and society. *Pers. Med.* **2013**, *10*, 565–576. [CrossRef]
77. Woolf, S.; Atkins, D. The evolving role of prevention in health care. *Am. J. Prev. Med.* **2001**, *20*, 13–20. [CrossRef]
78. Friesen, M.C.; Hoar Zahm, S.; Ward, M.H.; Silverman, D.T. Chapter 42—Occupational cancer. In *Women and Health*, 2nd ed.; Goldman, M.B., Troisi, R., Rexrode, K.M., Eds.; Academic Press: Cambridge, MA, USA, 2013; pp. 629–645. ISBN 978-0-12-384978-6.
79. European Commission (Ed.) *Occupational Health and Safety Risks in the Healthcare Sector: Guide to Prevention and Good Practice*; Social Europe; Publishing Office of the European Union: Luxembourg, 2011; ISBN 978-92-79-19454-2.
80. Loosemore, M.; Andonakis, N. Barriers to implementing OHS reforms—The experiences of small subcontractors in the Australian construction industry. *Int. J. Proj. Manag.* **2007**, *25*, 579–588. [CrossRef]
81. Quinlan, M. Organisational restructuring/downsizing, OHS regulation and worker health and wellbeing. *Int. J. Law Psychiatry* **2007**, *30*, 385–399. [CrossRef]
82. Garfield, E. The history and meaning of the journal impact factor. *JAMA* **2006**, *295*, 90. [CrossRef]
83. Leydesdorff, L. Mapping interdisciplinarity at the interfaces between the science citation index and the social science citation index. *Scientometrics* **2007**, *71*, 391–405. [CrossRef]
84. Caon, M. Gaming the impact factor: Where who cites what, whom and when. *Australas. Phys. Eng. Sci. Med.* **2017**, *40*, 273–276. [CrossRef]
85. Corvino, A.; Garzillo, E.; Arena, P.; Cioffi, A.; Monaco, M.G.L.; Lamberti, M. Augmented reality for health and safety training program among healthcare workers: An attempt at a critical review of the literature. In Proceedings of the 1st International Conference on Human Systems Engineering and Design (IHSED2018): Future Trends and Applications, Champagne-Ardenne, France, 25–27 October 2018; p. 715.
86. Belingheri, M.; Paladino, M.E.; Riva, M.A. Beyond the assistance: Additional exposure situations to COVID-19 for healthcare workers. *J. Hosp. Infect.* **2020**, *105*, 353. [CrossRef] [PubMed]
87. Greenberg, N. Mental health of health-care workers in the COVID-19 era. *Nat. Rev. Nephrol.* **2020**, *16*, 425–426. [CrossRef] [PubMed]
88. Rim, K.-T.; Lim, C.-H. Biologically hazardous agents at work and efforts to protect workers' health: A review of recent reports. *Saf. Health Work* **2014**, *5*, 43–52. [CrossRef] [PubMed]
89. Rapisarda, V.; Loreto, C.; Vitale, E.; Matera, S.; Ragusa, R.; Coco, G.; Rapisarda, L.; Ledda, C. Incidence of sharp and needle-stick injuries and mucocutaneous blood exposure among healthcare workers. *Future Microbiol.* **2019**, *14*, 27–31. [CrossRef] [PubMed]

International Journal of
Environmental Research and Public Health

MDPI

Article

Tuberculosis and Other Airborne Microbes in Occupational Health and Safety

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], Pilar Ruiz-Martínez [3], Manuel Vaquero-Abellán [4,5], María Dolores Redel-Macías [2] and Pilar Aparicio-Martínez [4,5,*]

1 SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de
2 Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C.-A.); ig1remam@uco.es (M.D.R.-M.)
3 GC24 Clinical and Molecular Microbiology, Instituto Maimónides, Facultad Medicina y Enfermería, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; mi1rumap@uco.es
4 GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; en1vaabm@uco.es
5 Departamento de Enfermería, Fisioterapia y Farmacología, Universidad de Córdoba, Campus de Menéndez Pidal, 14071 Córdoba, Spain
* Correspondence: n32apmap@uco.es; Tel.: +34-6-7972-7823

Received: 15 July 2020; Accepted: 25 September 2020; Published: 28 September 2020

Abstract: Airborne pathogens and non-malignant infectious diseases such as tuberculosis are highly contagious and can have severe effects on healthcare workers. The symptoms of these diseases take time to manifest, which can prevent workers from noticing that they have been exposed until symptoms appear. The current paper sought to assess the occupational safety and preventative measures taken in laboratories in Spain, and to compare these measures with those reported by other studies worldwide. A cross-sectional study of workers (35–50 years old) was conducted using a web survey ($N = 30$), and a bibliometric analysis was carried out in the Scopus database (92 documents were selected). The occupational safety and health measures were inadequate, according to the opinions of the workers. The training ($p < 0.01$), the amount of work ($p < 0.05$), and how the workers followed their protocols ($p < 0.001$) were linked to incidents and exposure to airborne pathogens. The most significant previous publication was a report (848 citations) stating that the previous variables linked to exposure are vital for prevention. Most works focused on countries like the U.S.A. ($p = 0.009$) were reviews, with a limited number of studies focused on occupational safety.

Keywords: tuberculosis; laboratories; work environment

1. Introduction

Since the 18th century, when biological agents first came to be identified and defined, different countries have developed methods to prevent and control outbreaks [1]. The first efforts to control environmental factors, such as production, appeared in England during the Industrial Revolution [2]. During this period, the concept of occupational safety and health (O.S.H.) was first defined [3]. Subsequently, countries started to develop methods to control pathogens among their populations [4], such as Spain's attempts in the early 20th century to control the Spanish flu [5]. Nevertheless, only when the World Health Organization (WHO) highlighted the need for a series of pathogen-control measures to ensure the health of the working population in 1985 were such methods included and implemented in work environments [6].

In the European Union, a Council Directive called the 89/391/EEC, also known as Framework Directive, approved an occupational safety directive for the first time in 1989, focusing on improving

measures to guarantee the safety and health of workers. This directive established the fundamental principles for occupational safety described a century earlier [7,8]. However, it was not until 2004 that this directive proved that the involvement of standard legislation and the government in health and safety at work has a positive influence [8,9]. Since then, public administrations have created policies and structures to ensure the prevention of risks and promote and improve working conditions [10,11]. In this sense, maintaining workers' health has continued to be a crucial element in managing the public health of the population. However, each government has different ways of addressing the health of its workers. Governments must understand their workers and the effects of their work on their health [12,13].

One work environment that provides greater threats to its workers than other environments is health centers. Healthcare workers are exposed to many different biological pathogens, including human immunodeficiency virus, hepatitis B virus, and tuberculosis [1,14,15]. In this population, the rate of accidents and diseases related to work is around 3.2% [2]. The transmission of these agents among health professionals depends on a series of factors, the most important of which are the type of activity carried out by the worker and the effectiveness of the preventive interventions carried out [16,17]. Airborne pathogens and associated chronic respiratory diseases such as tuberculosis are highly contagious and can have severe effects on the health of workers [18]. Moreover, the symptoms of these diseases take time to manifest in the airways, which can prevent workers from realizing they have been exposed after symptoms begin [19–21]. For tuberculosis, which is caused by *Mycobacterium tuberculosis* (a Level 3 organism based on the biological risk it represents), public concern is based on the prevalence of the general population and healthcare workers that suffer from the disease [22]. In a report of WHO, it was estimated in 2015 that up to 2 billion people around the world suffer from a latent state of tuberculosis [23], which remains concerningly prevalent in low-risk countries, such as Italy [24]. In Italy in 2015, 2.1% of healthcare workers were diagnosed with latent tuberculosis infections [25]. Similar results were found in a previous systematic review which detailed that 2.9% of healthcare workers in low-incidence countries had latent tuberculosis [26].

Many factors may contribute to accidental exposure to a biological agent, although the main factors are still a lack of experience, skills, or knowledge in handling materials, and anxiety, fatigue, and a lack of care for oneself or other professionals [27]. For tuberculosis, the lack of knowledge about its transmission, the relevant preventive and biosafety measures, and the diagnosis of the disease seems to play an important role [25]. Moreover, the current situation with the new pandemic has highlighted the lack of professional and personal protective equipment (PPE) and adequate training provided in hospitals, which could have a major impact on the prevention of airborne pathogens [28]. Moreover, the latest studies have highlighted the need to create guidelines and training programs for undergraduate students and health professionals, especially for tuberculosis and other airborne pathogens [29]. In this sense, different studies have highlighted the importance of ensuring that healthcare workers receive training and have control measures in place, although these activities are difficult to implement [25,30,31].

Laboratories and research centers where diagnostic tests are carried out carry an inherent risk for their workers, who are commonly exposed to different pathogens, including tuberculosis. Nevertheless, most studies have focused on healthcare workers or students (mainly doctors and nurses) and based on contact with patients [26]. For laboratories and research centers, most available data relate to the early nineties, reporting a prevalence of around 7.8% in the United States or 6.7 clinical laboratory technicians out of 100,000 [32]. Other studies carried out in Korea stated that the risk of contracting tuberculosis in a laboratory is 1.4 percentage higher for microscopy technicians and 7.8 for culture/defense and sciences technicians compared to non-laboratory workers [33]. Different studies have also demonstrated that laboratories are vital for the follow-up and treatment of tuberculosis [34], with updates to their protocols and improvements in access to (and training for) PPE being fundamental [35,36]. Based on these previous observations, the current paper primarily sought to determine the conditions in laboratories related to occupational safety and preventative measures, mainly in Spain. The secondary objective

54. Turin, T.; Ahmed, S.; Vaska, M. Conducting a Literature Review in Health Research: Basics of the Approach, Typology and Methodology. *J. Natl. Heart Found. Bangladesh* **2016**, *5*, 44–51.
55. Gopalakrishnan, S.; Ganeshkumar, P. Systematic Reviews and Meta-analysis: Understanding the Best Evidence in Primary Healthcare. *J. Fam. Med. Prim. Care* **2013**, *2*, 9–14.
56. Altman, D.; Simera, I. Using Reporting Guidelines Effectively to Ensure Good Reporting of Health Research. In *Guidelines for Reporting Health Research: A User's Manual*; Wiley: Hoboken, NJ, USA, 2014; pp. 32–40.
57. Parrish, N.M.; Carroll, K.C. Role of the Clinical Mycobacteriology Laboratory in Diagnosis and Management of Tuberculosis in Low-Prevalence Settings. *J. Clin. Microbiol.* **2011**, *49*, 772. [CrossRef] [PubMed]
58. Bowen, R.; Benavides, R.; Colón-Franco, J.M.; Katzman, B.M.; Muthukumar, A.; Sadrzadeh, H.; Straseski, J.; Klause, U.; Tran, N. Best practices in mitigating the risk of biotin interference with laboratory testing. *Clin. Biochem.* **2019**, *74*, 1–11. [CrossRef] [PubMed]
59. Ombelet, S.; Ronat, J.-B.; Walsh, T.; Yansouni, C.P.; Cox, J.; Vlieghe, E.; Martiny, D.; Semret, M.; Vandenberg, O.; Jacobs, J. Clinical bacteriology in low-resource settings: Today's solutions. *Lancet Infect. Dis.* **2018**, *18*, e248–e258. [CrossRef]
60. Weinstein, R.A.; Singh, K. Laboratory-Acquired Infections. *Clin. Infect. Dis.* **2009**, *49*, 142–147.
61. Jilcha, K.; Kitaw, D. Industrial occupational safety and health innovation for sustainable development. *Eng. Sci. Technol. Int. J.* **2017**, *20*, 372–380. [CrossRef]
62. Parsons, L.M.; Somoskövi, Á.; Gutierrez, C.; Lee, E.; Paramasivan, C.N.; Abimiku, A.; Spector, S.; Roscigno, G.; Nkengasong, J. Laboratory Diagnosis of Tuberculosis in Resource-Poor Countries: Challenges and Opportunities. *Clin. Microbiol. Rev.* **2011**, *24*, 314. [CrossRef]
63. Gagliardi, D.; Marinaccio, A.; Valenti, A.; Iavicoli, S. Occupational Safety and Health in Europe: Lessons from the Past, Challenges and Opportunities for the Future. *Ind. Health* **2012**, *50*, 7–11. [CrossRef]
64. de la Fuente, V.S.; López, M.A.C.; González, I.F.; Alcántara, O.J.G.; Ritzel, D.O. The impact of the economic crisis on occupational injuries. *J. Saf. Res.* **2014**, *48*, 77–85. [CrossRef]
65. Kimman, T.G.; Smit, E.; Klein, M.R. Evidence-based biosafety: A review of the principles and effectiveness of microbiological containment measures. *Clin. Microbiol. Rev.* **2008**, *21*, 403–425. [CrossRef]
66. Sadaf, R.; Munir, T.; Farrukh, S.; Abbasi, S. Prevalence of latent tuberculosis infection in healthcare workers in tertiary care hospitals of Pakistan. *Pak. J. Med. Sci.* **2020**, *36*, 198–202. [CrossRef] [PubMed]
67. Erawati, M.; Andriany, M. The Prevalence and Demographic Risk Factors for Latent Tuberculosis Infection (LTBI) Among Healthcare Workers in Semarang, Indonesia. *J. Multidiscip. Healthc.* **2020**, *13*, 197–206. [CrossRef] [PubMed]
68. Zhang, X.; Jia, H.; Liu, F.; Pan, L.; Xing, A.; Gu, S.; Du, B.; Sun, Q.; Wei, R.; Zhang, Z. Prevalence and Risk Factors for Latent Tuberculosis Infection among Health Care Workers in China: A Cross-Sectional Study. *PLoS ONE* **2013**, *8*, e66412. [CrossRef] [PubMed]
69. Shinnick, T.M.; Iademarco, M.F.; Ridderhof, J.C. National plan for reliable tuberculosis laboratory services using a systems approach. Recommendations from CDC and the Association of Public Health Laboratories Task Force on Tuberculosis Laboratory Services. *Morb. Mortal. Wkly. Rep.* **2005**, *54*, 1–12.
70. Centers for Disease Control and Prevention (CDC). Plan to combat extensively drug-resistant tuberculosis: Recommendations of the Federal Tuberculosis Task Force. *Morb. Mortal. Wkly. Rep.* **2009**, *58*, 1–43.

International Journal of
Environmental Research and Public Health

MDPI

Article

Occupational Safety and Health Training for Undergraduates Nursing Students: A Spanish Pilot

Esther Vaquero-Álvarez [1], Antonio Cubero-Atienza [2], María Pilar Martínez-Jiménez [3,4], Manuel Vaquero-Abellán [5,6], María Dolores Redel-Macías [2] and Pilar Aparicio-Martínez [5,6,*]

1 SRH Kliniken Landkreis Sigmaringen, Hohenzollernstraße 40, 72488 Sigmaringen, Germany; esther.vaquero@srh.de
2 Departamento Ingeniería Rural, Ed Leonardo da Vinci, Campus de Rabanales, Universidad de Córdoba, 14071 Córdoba, Spain; ajcubero@uco.es (A.C.-A.); ig1remam@uco.es (M.D.R.-M.)
3 Applied Physics, Radiology and Physics Medicine Department, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, 14014 Cordoba, Spain; fa1majip@uco.es
4 Simulation Models in Energy, Transport, Physics, Engineering, Occupational Hazard Researcher Group, Junta de Andalucía, and Dpt. Applied Physics, Albert Einstein Building, Campus de Rabanales, Universidad de Cordoba, 14014 Cordoba, Spain
5 GC12 Clinical and Epidemiological Research in Primary Care, Instituto Maimónides, Campus de Menéndez Pidal, Universidad de Córdoba, 14071 Córdoba, Spain; en1vaabm@uco.es
6 Departamento de Enfermería, Fisioterapia y Farmacología, Campus de Menéndez Pidal, Universidad de Córdoba, 14014 Córdoba, Spain
* Correspondence: n32apmap@uco.es; Tel.: +34-679-727-823

Received: 6 October 2020; Accepted: 10 November 2020; Published: 12 November 2020

Abstract: Most of blood borne and airborne pathogens are highly contagious, harmful and have prevalence among healthcare workers. In this group, healthcare students, especially nursing undergraduates, have even higher risk to be exposed and suffered a contagious accident. One of the main pillars to prevent exposure to such pathogens and decrease accidents seems to be through education. A prospective observational educational research focused on quantifying the students' knowledge, and prevention culture was carried out. The educational approach based on the development of a technological tool, its integration in the students' education, and posterior assessment. The Chi-square, ANOVA, Kruskal–Wallis, Man–Whitney U, and Spearman correlations were used to determine the effect of such educational methodology. The results, previous to the integration of the educational approach, showed differences between the elementary and proficient knowledge and correct procedure in each academic year ($p < 0.05$), being the best year the third academic year. The mean of elementary knowledge among second year students after the inclusion of the educational methodology improved for 2017/2018 with a mean of 7.5 (1.11) and in 2018/2019 with 7.87 (1.34). This study argued that the educational approach proposed could improve the prevention culture and knowledge among students and future healthcare professionals.

Keywords: prevention culture; continuous training; web platform; nursing students

1. Introduction

Since the first time that biological exposure to blood was studied by Ramazzini [1], more pathogens have been described as hazardous, being up to 44% of them viral [2]. Most of the current harmful microorganisms are blood borne, such as human immunodeficiency virus (H.I.V.), and airborne pathogens, such as tuberculosis, being highly presented in the daily day of healthcare workers [3,4]. These workers are at risk of being exposed to diverse pathogens, from mortal (i.e., Ebola) to highly contagious viruses (i.e., Sars-covid-19) via material or surfaces and corporal fluids [5,6].

This threat among healthcare workers continues to be presented and has economical and health repercussions in the healthcare systems and the workers' physical and mental health [5,6]. In order to decrease this hazard, serval educational programs have been created and implemented to raise awareness among healthcare workers regarding risk and prevention, including hand washing or disposal in specific resistant containers [7]. At the same time, organizations and political structures, such as National Health System in England [5], have created prevention policies and updated guidelines to decrease the jeopardy of exposure among healthcare workers, protect their health, and concise these workers [8–10].

Among the measures taken by the organizations, the education (initial or continuous training) of their healthcare worker has been of the main pillars to prevent biological exposure and accidents [11]. Despite the modifications and inclusion of initial and continuous training carried out during more than two decades, the level of knowledge and compliance with universal precautions procedures continues to be limited [12,13]. This difficulty in achieving optimum levels of knowledge seems to be linked to the reduced safety culture [14]. The safety culture, which can be defined as values shared among workers regarding what is considered necessary among the healthcare workers, has been defined as a key point for occupational and health measures in different working areas [14]. One stage of the workers' life that the learning process is more dynamic and adapting to changes is in the university years [8].

As future young workers, healthcare students are more drive to engage themselves in risky situations that they are not prepared to face, based on their willingness to take on challenges and more responsibilities. Moreover, the students rarely received information regarding the rate of the biological accidents that they had suffered during the practice [15]. Among the undergraduate healthcare students, the nursing students have a higher risk of exposure to pathogens because of their direct contact with the patients, lack of knowledge and safety culture, and more willingness to take risks [16]. Furthermore, data about biological accidents among nurses' students continues to reduce, except from previous studies carried out in other countries, such as Italy [17,18] or China [19]. Moreover, only a few researchers have recently studied the incidence of biological accidents, knowledge and safety culture among nursing students in Spain [20].

2. Background

The evaluation of knowledge among healthcare students has been considered an upholder at improving their education and their safety culture, resulting in compromising the occupational health and security measures taken by the students [21]. The development of new educational methodologies [22] to improve the training and knowledge about preventing an accident and protocols post-exposition are a main key to improve the students safety culture. Simultaneously, educational institutions and researchers have created models and new methodological approaches based on computers and other information and communication technologies (I.C.T.s) to be integrated in the classroom [12]. These new methodologies search to adapt and develop platforms or applications via gamification or interactive environments, such as virtual reality, according to the organizations, students or professors' needs [23,24]. All these tools are integrated into a platform or used individually, allowing ubiquitous, electronic or blended learning [25]. Previous works have accomplished several functional software applications available for mobile devices focused on nursing students [24,26].

Therefore, new teaching methodologies, based on ICTs and focused on improving the training and information about biological accidents and prevention, holds a great importance for nursing students [27]. These technologies were created to develop tutorials, games, virtual laboratories, videos, simulations, and virtual reality [24,27]. These technological and educational tools developed in computer-based training have four pillars to achieve their intended goal (feedback, appealing experience, creative design, and assessment of designed program) [28]. These pillars seem to positively improve the knowledge and training educational approaches via applications [28].

43. Erawati, M.; Andriany, M. The Prevalence and Demographic Risk Factors for Latent Tuberculosis Infection (LTBI) among Healthcare Workers in Semarang, Indonesia. *J. Multidiscip. Healthc.* **2020**, *13*, 197–206. [CrossRef]
44. Arcanjo, R.V.G.; Christovam, B.P.; de Souza, N.V.D.O.; Silvino, Z.R.; Da Costa, T.F. Knowledge and practices of nursing workers on occupational risks in primary health care: An intervention trial. *Enfermería Glob.* **2018**, *17*, 200. [CrossRef]
45. Nykänen, M.; Puro, V.; Tiikkaja, M.; Kannisto, H.; Lantto, E.; Simpura, F.; Uusitalo, J.; Lukander, K.; Räsänen, T.; Teperi, A.-M. Evaluation of the efficacy of a virtual reality-based safety training and human factors training method: Study protocol for a randomised-controlled trial. *Inj. Prev.* **2020**, *26*, 360–369. [CrossRef] [PubMed]
46. Barisone, M.; Bagnasco, A.; Aleo, G.; Catania, G.; Bona, M.; Gabriele Scaglia, S.; Zanini, M.; Timmins, F.; Sasso, L. The effectiveness of web-based learning in supporting the development of nursing students' practical skills during clinical placements: A qualitative study. *Nurse Educ. Pract.* **2019**, *37*, 56–61. [CrossRef] [PubMed]

21st of December, 2020

ABSTRACT ACCEPTANCE LETTER

This is a confirmation that the abstract entitled:

"TRAINING HEALTHCARE WORKS USING AN EDUCATIONAL TECHNOLOGICAL APPROACH: A PRELIMINARY STUDY"

Author(s): Esther Vaquero-Álvarez, Gerardo Pedrós Perez, Manuel Vaquero Abellán, Maria Pilar Martinez-Jimenez, Pilar Aparicio Martínez

has been accepted as VIRTUAL presentation at inted2021.

Name of event: INTED2021 (14th annual International Technology, Education and Development Conference)
Dates: 8th-9th of March, 2021
Organisation: IATED

INTED2021 Local Organising Committee

TESIS DOCTORAL

FEBRERO DE 2021